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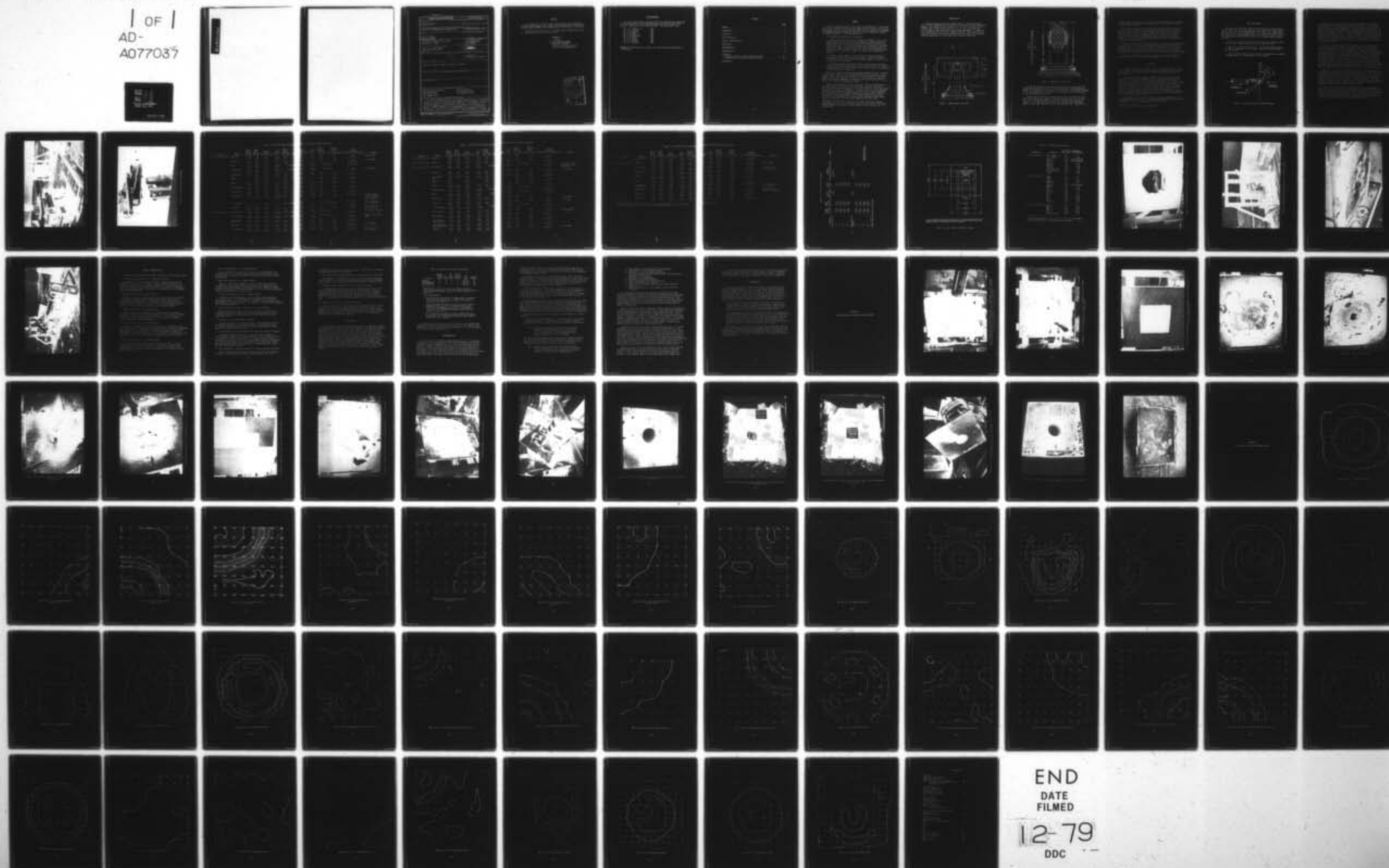

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 14 NSWC/TR-79-376
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER: 9
4. TITLE (and Subtitle): 6 ROCKET MOTOR BLAST EFFECTS AND PROPOSED ABLATIVE PROTECTION FOR RAM LAUNCHING SYSTEM EX 43
5. TYPE OF REPORT & PERIOD COVERED: Final rept.
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): 10 Earl E. Biermann, Allen B. Coates
8. CONTRACT OR GRANT NUMBER(s): 16
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Surface Weapons Center (G25), Dahlgren, VA 22448
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 64369N, S0167-8A, 17 S0167-8A-001
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Sea Systems Command, Washington, DC 20362
12. REPORT DATE: 11 Oct[redacted]79
13. NUMBER OF PAGES: 91
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 12 91
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited.
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):

RAM Launching System EX 43	Ablative Materials
RIM 116A Missile	Fire Retardant Foam
Mk 36 Rocket Motor	Fire Retardant Resin
Impingement Tests	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The test program described in this report was designed to: (1) investigate the severity of EX 43 launcher and ship damage caused by exhaust blast during flyaway and inadvertant restrained RIM 116A missile firings and (2) investigate and recommend the type and amount of suitable protective materials required to prevent degradation in the impingement area. The four materials tested in the last phase of this program have been recommended for further qualification testing for survivability in a simulated shipboard environment.

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UNCLASSIFIED 391598

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FOREWORD

The investigation and test series reported herein were conducted by the Naval Surface Weapons Center (NSWC) and were supported by the Naval Sea Systems Command (NAVSEA) under SEATASK 404-50015-009-1-S0167 of June 1979.

This report was reviewed by C. W. Brandts, Head, Programs Branch; and R. J. Arthur, Head, Missile Systems Division.

Released by:

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Assistant for Weapons Systems
Weapons Systems Department

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Distribution/	
Availability Codes	
Dist A	Avail and/or special

ACKNOWLEDGEMENT

The author acknowledges with appreciation the assistance and cooperation received from members of other NSWC departments who were involved in the successful completion of this testing program. Key contributors* were

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CONTENTS

	Page
SUMMARY	1
INTRODUCTION	2
BACKGROUND	4
TEST DESCRIPTION	5
MATERIAL CHARACTERISTICS	19
CONCLUSIONS	21
RECOMMENDATIONS	22
NEW MATERIALS	25
APPENDIXES	
A--SELECTED MATERIALS, BEFORE AND AFTER FIRINGS	A-1
B--CONTOUR PLOTS OF ABLATIVE MATERIAL RESULTS	B-1
DISTRIBUTION	

SUMMARY

The test program described in this report was designed to (1) investigate the severity of EX 43 launcher and ship damage caused by exhaust blast during flyaway and inadvertant restrained RIM 116A missile firings and (2) investigate and recommend the type and amount of suitable protective materials required to prevent degradation in the impingement area.

The program was conducted in three phases:

1. Phase I*--An oxy-acteylene torch flame that impinged on the various samples [American Society for Testing of Materials (ASTM) Designation E235-65T] was used in a screening process to eliminate unsuitable protective materials. This test was considered less severe than the actual motor blast; thus, it would not eliminate useable candidates from consideration. Fifteen different materials, which offered some possibility of surviving the rocket motor plume, were selected as candidates for Phase II.

2. Phase II--Larger samples of the 15 materials selected by Phase I were tested using the Mk 36 rocket motor blast. Phase III consisted of additional firings, restrained and flyaway, against 12 inch (30.5 cm) by 12 inch (30.5 cm) samples.

3. Four materials were tested with the Mk 36 rocket motors simulating a restrained condition during the initial portions of Phase III. Actual flyaway firings from a launching rail were conducted against two materials in the final portion of Phase III.

The criteria used to evaluate the candidate materials follow: resistance to rocket motor flame erosion, weathering capabilities and durability under normal traffic conditions, ease of application and repairability, and availability and cost effectiveness of materials. The four materials tested in Phase III have been recommended for further qualification testing for survivability in a simulated shipboard environment.

Shipboard environment (sun, wind, sea water, freezing and thawing, etc.) and normal everyday traffic (testing, maintenance, overhaul, and general) will have a deteriorating effect on any protective material used on the launcher base or ship structure. Consequently, a series of tests are to be conducted to measure water absorption, adhesion, vibration, shock, thermal expansion, etc. Firing tests will be conducted against the material after soaking it in salt water to determine whether it will spall or separate explosively as a result of water expansion or stream pressure generated by the exhaust heating. Results will be reported upon completion of these tests.

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* The details of the Phase I testing are included in William H. Barbour and Ottmar Dengel, *Ablative Properties of Blast Protection Materials*, Naval Surface Weapons Center Technical Report NSWC TR 79-409, Dahlgren, VA, (to be published).

INTRODUCTION

The RAM Launching System EX 43 (RAM LS EX 43) is designed (Figures 1 and 2) so that, depending on the elevation, the nozzles of the missiles while stowed in the launcher guide are within 6 to 12 in. (15 to 30 cm) of the launcher base, or they are as close as 36 in. (91 cm) to the ship deck. It is recognized that rocket motor exhaust plume impingement is a major design consideration of all missile launching systems. Even though this program was directed at satisfying the RAM LS EX 43 requirements, the data are considered applicable to all systems using the Mk 36 rocket motor.

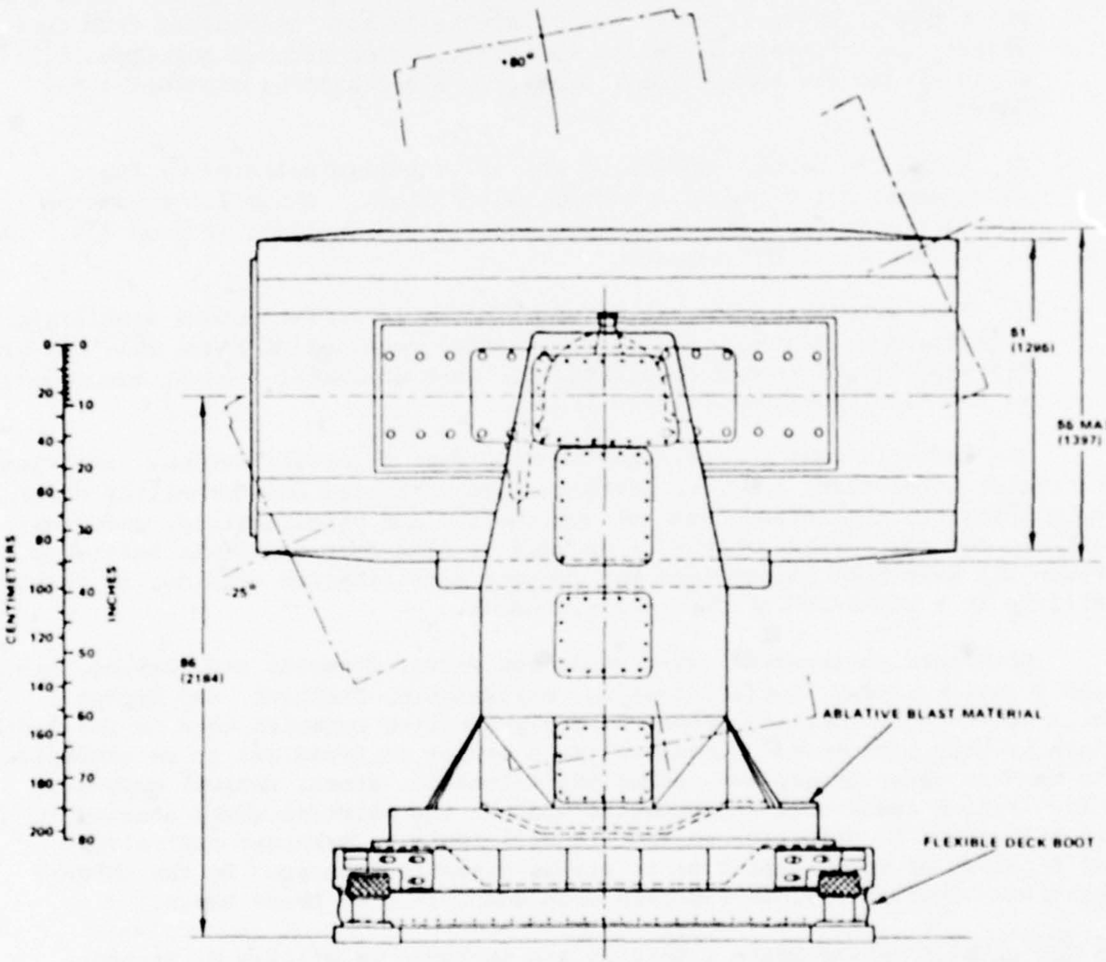

Figure 1. RAM Launcher, Side View

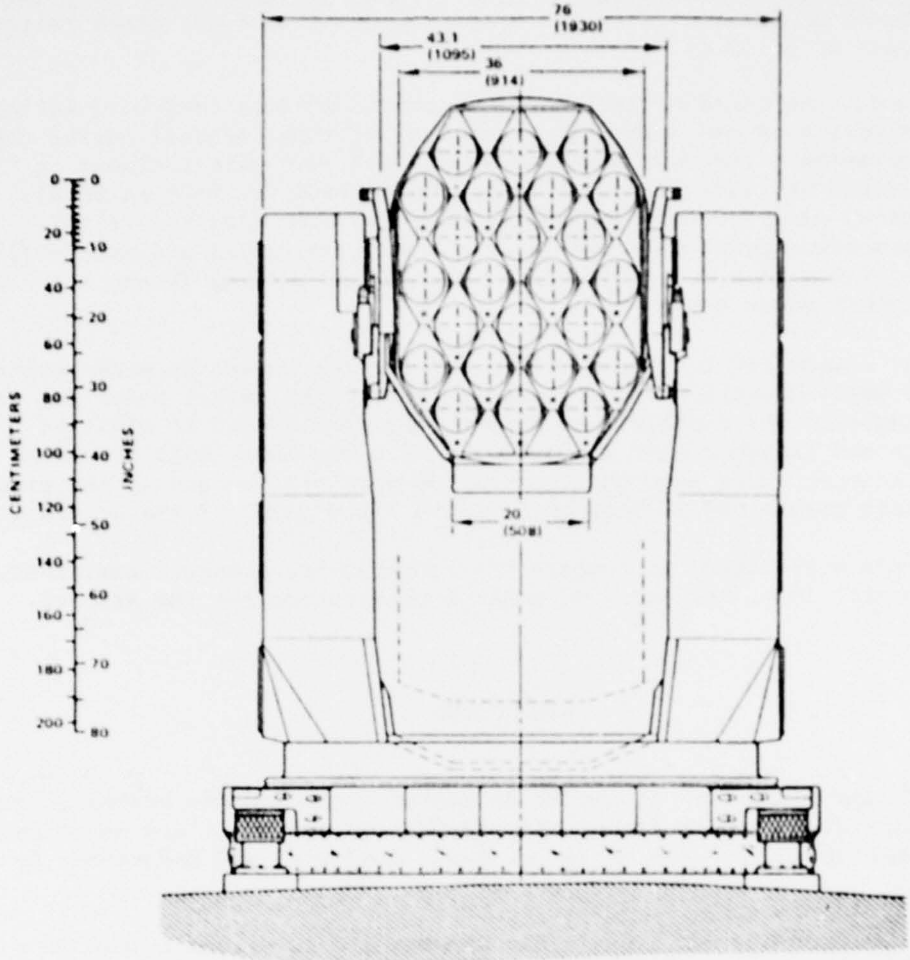

Figure 2. RAM Launcher, Rear View

During the selection of the ablative materials to be tested, many candidates were found that could be utilized for protection from extreme heat. However, high temperature is only part of the problem. The aluminum contained in the very high-velocity rocket motor gases compounds the errosive effects of the high-temperature gas flow.

A search was conducted to locate materials that could withstand rocket motor blast conditions. Samples of candidate materials [4 x 4 x 0.125 in. (10 x 10 x 0.32 cm)] were used in an initial oxy-acetylene screening test (Phase I). Cost and absence of asbestos [Occupational Safety and Health Administration (OSHA) regulations] were also considerations. Materials for

the final rocket motor blast tests (Phase II) were selected from this initial screening based on erosion rates and observations by test personnel relative to other types of failures.

To broaden the field of test results, and to achieve some correlation to previous test programs, materials tested at Redstone Arsenal during the Mk 56 rocket motor tests were provided (NSWC, N43) and were included in the Phase III series of tests. Control samples were selected from materials currently being used, or recommended for use, in other missile systems. Companies producing these selected materials were contacted and samples [12 x 12 x 1 in. (30 x 30 x 2.5 cm)] were purchased for testing (Phase III) in the Mk 36 rocket motor plume.

Holding stands for the rocket motor and for the materials were constructed (the latter could be varied for both distance from the rocket motor and impingement angle). The backplate to support the samples and to simulate the deck surface and launcher base was 0.75 in. (1.9 cm)-thick 6061 aluminum. Simulated launcher tubes were constructed and were used to assess the effects of inadvertant restrained firings both in the fired tube and the adjacent tubes.

Data were accumulated to compare the temperature, pressure sustained, overall material lost, and depth of maximum penetration for the samples.

BACKGROUND

The exhaust properties of the Mk 36 rocket motor and the probable blast erosion damage to the LS EX 43 and ship-associated equipment are noted below to provide background for the series of tests conducted and documented by this report.

The Mk 36 rocket motor used in the RAM missile is basically the same motor as that used in the SIDEWINDER missile. Although modifications were made to the rocket motor case, the propellant and nozzle are unchanged. The rocket motor plume contains, among other components, _•_ percent by weight of aluminum oxide (AL_2O_3). Flyaway and restrained rocket motor plumes can be directed at the base of the launcher and the ship structure, shipboard launchers, gun mounts, mines, torpedoes, and missiles or other explosive stores in proximity to the launcher. The rocket motor exhaust, at _•_ lb of thrust at a peak temperature of 5200°F with a burn time of _•_ sec and with its high AL_2O_3 content, presents untolerable effects on normal materials used in launcher or ship construction.

To ameliorate this situation, a materials search, investigation, and testing program were instituted to locate a material that could survive direct impingement of the Mk 36 rocket motor blast during firing.

•Values will be furnished by author on request.

TEST DESCRIPTION

The tests described herein have been separated into groups according to the distance of the ablative sample from the rocket motor nozzle and the angle at which the rocket plume impinged on the sample. The angles noted were measured from a plane perpendicular to the rocket motor plume (Figure 3). The rocket motor blast impingement angles and distances selected for this test were based on situations that could occur in normal elevation angles of launch:

1. The 6 in. (15 cm)/90° condition would simulate a high-angle launch with the motor exhaust impinging on the carriage base ring.

2. The 12 in. (30 cm)/32.5° and 36 in. (91 cm)/60° conditions would simulate an impingement on the launcher stand and the deck adjacent to the launcher.

3. The 36 in./90° condition would simulate an impingement on shipboard equipment mounted in close proximity to the launcher.

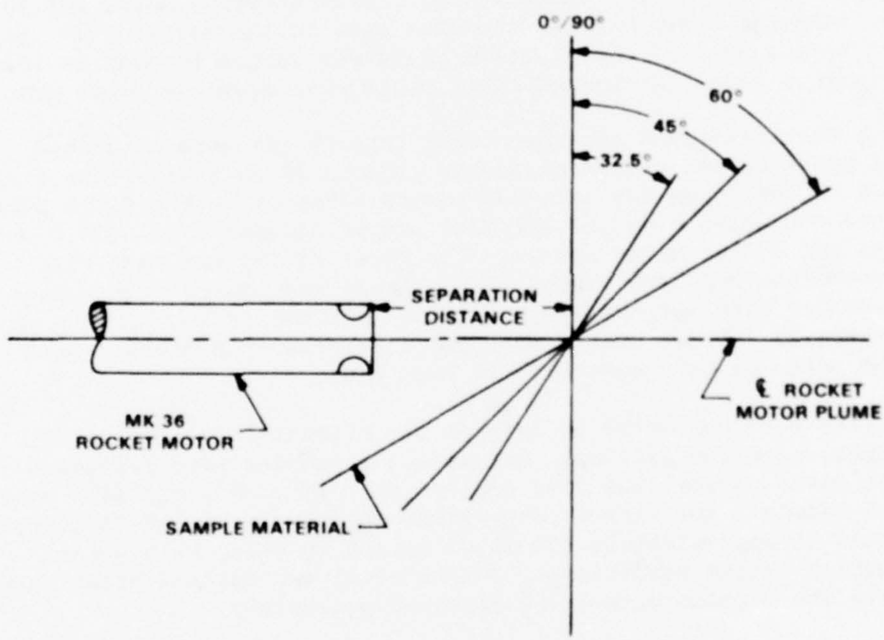

Figure 3. Rocket Motor Blast Impingement Angles

Figure 4 shows the restrained firing test arrangement. The material holding plate was adjustable in both angle and distance. The test materials were subjected to a complete motor burn. Selected materials, before and after firings, are shown in Appendix A. The test materials were weighed and gauged for thickness. Thermocouples were installed (when used) prior to the firings. After completion of the test, the materials were again weighed and accurately gauged for thickness. The gauging data were used to plot erosion contours for each sample. These contours, together with other pertinent information on the material type and test conditions, are included in Appendix B. The samples were gauged at 1-in. intervals in a two-dimensional grid. The values shown are measurements of the material thickness (in inches) remaining after each test firing.

Figure 5 shows the flyaway test arrangement. Tables 1 and 2 contain test results and pertinent data concerning restrained and flyaway tests. Figure 6 shows the various sizes of materials tested. Table 3 depicts the relative performance of the ablative material at impingement distances of 6.0, 12.0, and 36.0 in. at a 90° impingement angle. Data have been normalized for comparison with 12 x 12 in. samples of Haveg 41-N. Although these data provide an estimate of the performance of each material, it is qualitative and should be treated as such. The results of a firing against a 0.75-in. (1.9 cm)-thick 6061 aluminum plate and a 1-in. (2.5 cm)-thick steel plate are shown in Figures 7 and 8, respectively. These firings were conducted as control samples to illustrate the need for a protective covering for the ship deck, the launcher area, and the launcher base in the event of an ignited and restrained rocket motor. The aluminum plate was burned through in less than 1 sec (Figure 9 shows the burned steel plate with aluminum oxide coating).

Tests that used simulated launcher tubes (Figure 10) were conducted to examine the pressure and reflected energy effects of an inadvertent firing on the back end of the guide and canister covers adjacent to the fired tube. These tests were conducted with the ablative sample located 6 in. (15.2 cm) from and 90° to the rocket motor nozzle. The first firing was made with no ablative protection over the fiberglass launcher end plate. The second firing was conducted with approximately 1/4 in. (0.6 cm) of Dow Corning material 93-104 (with graphite fibers) coated over the fiberglass end plate. Both temperature and pressure were monitored in each case.

Flyaway tests were conducted to examine the effects on the ablative material of normal repeated firings. The ablative samples were located 6 in. from the rocket motor nozzle, and four angles (90°, 15°, 30°, and 45°) were chosen for each sample. The fire-through latch spring of the LAU-3A launching rail was adjusted to approximately 800 lb of thrust in order to simulate the EX 31 launching system conditions. The material was weighed after each firing to enable the erosion rate to be examined accurately.

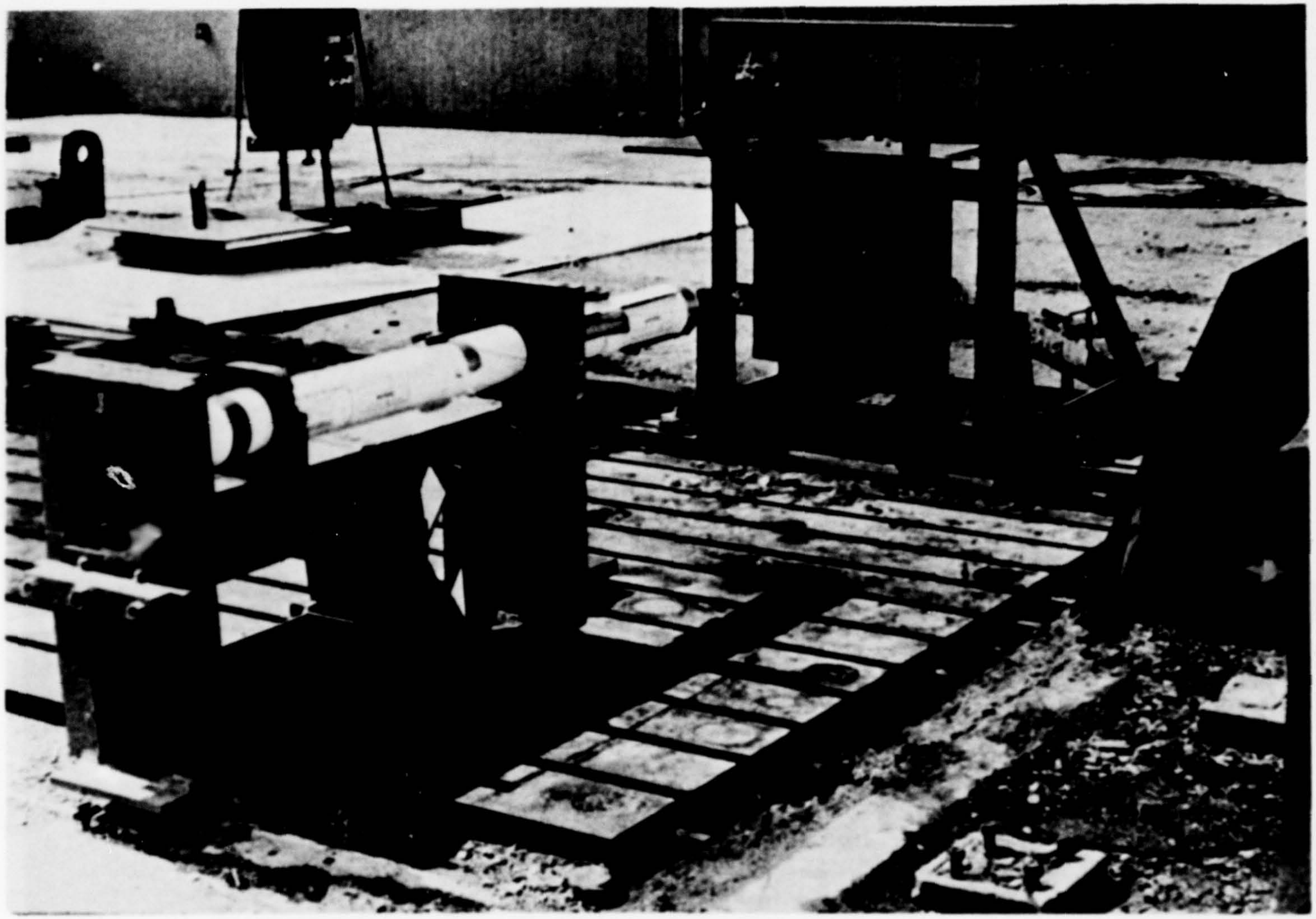

Figure 4. Restrained Firing Test Setup

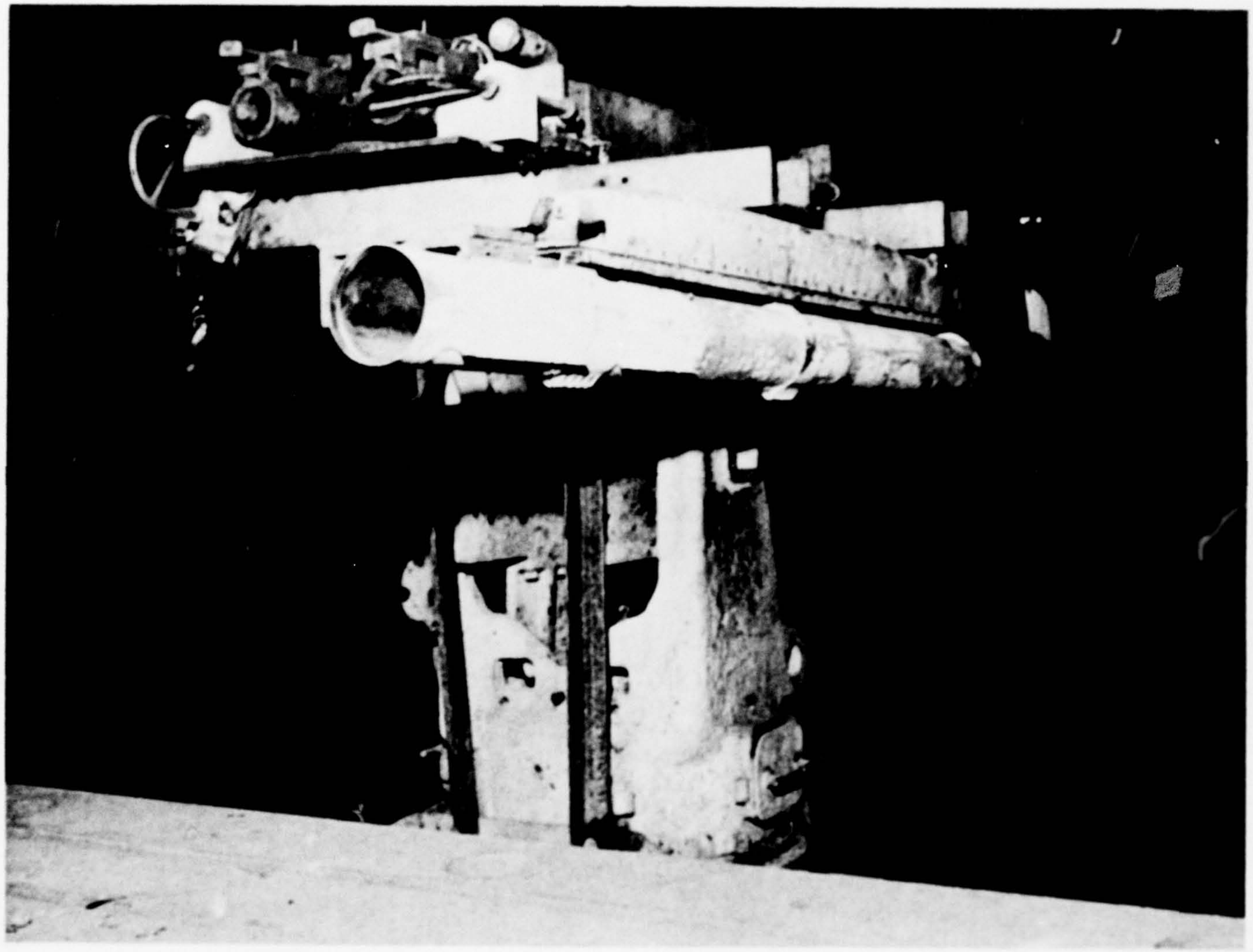

Figure 5. Flyaway Launcher Arrangement

Table 1. Firing Test Data; Restrain

Location	Material	Weight Before Firing [lb (kg)]	Weight After Firing [lb (kg)]	Original Density [lb/in.^{3} (g/cm^3)]	Percent Weight Loss	Maximum Surface Recession [in. (cm)]	[
36 in. (91.4 cm) at 90°	Haveg 41-N	8.98 (4.07)	7.49 (3.39)	0.07 (1.83)	16.6 (16.60)	0.46 (1.18)	
	Haveg 41-N	10.05 (4.55)	9.61 (4.35)	0.07 (1.83)	17.5 (17.50)	0.42 (1.05)	
	Kevlar	6.35 (2.88)	5.48 (2.48)	0.04 (1.22)	54.8* (54.80)*	Burned Th	
	Dynatherm E-340	5.81 (2.63)	4.36 (1.98)	0.04 (1.11)	99.8* (99.80)*	Burned Th	
	Fire Retardant FR-1	7.40 (3.35)	6.83 (3.09)	0.06 (1.55)	30.8 (30.80)	0.43 (1.10)	
	MXBE-350	--- (---)	9.83 (4.45)	0.06 (1.69)	--- (---)	0.37 (0.93)	
	MXB-360	10.49 (4.75)	10.15 (4.60)	0.06 (1.80)	12.8 (12.80)	0.42 (1.06)	
	93-104 w/Graphite	7.69 (3.48)	6.90 (3.12)	0.05 (1.47)	41.2 (41.20)	0.29 (0.74)	
	Fondu Fyre XB-1	18.19 (8.24)	17.63 (7.99)	0.10 (2.88)	12.3 (12.30)	0.39 (1.00)	
	German Material	17.34 (7.87)	15.85 (7.19)	0.06 (1.66)	13.44** (13.44)	0.45 (1.13)	
	0.75 In. Aluminum (6061)	--- (---)	--- (---)	0.10 (2.71)	--- (---)	Burned Through	
	Steel Plate	161.00 (72.93)	157.68 (71.52)	0.28 (7.84)	8.25 (8.25)	0.51 (1.29)	
36 in. (91.4 cm) at 32.5°	93-104 w/Graphite	7.45 (3.38)	6.12 (2.78)	0.05 (1.47)	35.60* (35.60)*	Burned Through	
	93-104 w/Graphite	7.68 (3.48)	5.42 (2.46)	0.05 (1.47)	29.40* (29.40)*	Burned Through	
	Fire Retardant FR-1	7.11 (3.23)	6.33 (2.87)	0.06 (1.55)	22.00 (22.00)	0.47 (1.20)	
	Haveg 41-N	9.19 (4.17)	7.70 (3.49)	0.07 (1.83)	16.20 (16.20)	0.53 (1.34)	
	Hitco w/Refrasil	6.92 (3.14)	6.16 (2.79)	0.06 (1.61)	7.60** (11.00.	0.39 (1.00)	

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ble 1. Firing Test Data; Restrained

iginal ensity n.^{3} (g/cm^3)]	Percent Weight Loss	Maximum Surface Recession [in. (cm)]	Maximum Recession Rate [in./sec (cm/sec)]	Thermal Conductivity [Btu/ft/hr/°F (cal/sec/cm/°C)]	Comments
0.07 (1.83)	16.6 (16.60)	0.46 (1.18)	0.09 (0.23)	0.20 (0.84×10^{-3})	Control sample
0.07 (1.83)	17.5 (17.50)	0.42 (1.05)	0.20 (0.20)	0.20 (0.84×10^{-3})	Control sample
0.04 (1.22)	54.8* (54.80)*	Burned Through		Not Available	
0.04 (1.11)	99.8* (99.80)*	Burned Through		0.20 (0.77×10^{-3})	Control sample
0.06 (1.55)	30.8 (30.80)	0.43 (1.10)	0.08 (0.21)	~0.10 ($.41 \times 10^{-3}$)	
0.06 (1.69)	--- (---)	0.37 (0.93)	0.07 (0.18)	0.20 (0.83×10^{-3})	
0.06 (1.80)	12.8 (12.80)	0.42 (1.06)	0.08 (0.20)	0.37 (1.53×10^{-3})	
0.05 (1.47)	41.2 (41.20)	0.29 (0.74)	0.06 (0.14)	0.20 (0.84×10^{-3})	
0.10 (2.88)	12.3 (12.30)	0.39 (1.00)	0.08 (0.19)	1.00 (4.13×10^{-3})	
0.06 (1.66)	13.44** (13.44)	0.45 (1.13)	0.09 (0.22)	Not Available	Contains asbestos; tested as comparison; 15 x 15 in. (38.1 x 38.1 cm) sample
0.10 (2.71)	--- (---)	Burned Through	<1.0 sec <1.0 sec	~96.0 @ 77°F (0.40)	Control sample 24 x 24 in. (61 x 61 cm)
0.28 (7.84)	8.25 (8.25)	0.51 (1.29)	0.10 (0.25)	~22.0 @ 32°F (0.09)	Control sample 24 x 24 in. (61 x 61 cm)
0.05 (1.47)	35.60* (35.60)*	Burned Through		0.20 (0.84×10^{-3})	Two samples on one plate
0.05 (1.47)	29.40* (29.40)*	Burned Through		0.20 (0.84×10^{-3})	Repeat of above--single sample
0.06 (1.55)	22.00 (22.00)	0.47 (1.20)	0.09 (0.23)	~0.10 (0.41×10^{-3})	
0.07 (1.83)	16.20 (16.20)	0.53 (1.34)	0.10 (0.26)	0.20 (0.84×10^{-3})	Control samples
0.06 (1.61)	7.60** (11.00,	0.39 (1.00)	0.08 (0.19)	0.23 (0.96×10^{-3})	10 x 10 in. (25.4 x 25.4 cm) sample

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Table 1. Firing Test Data; Restrained (

Location	Material	Weight Before Firing [lb (kg)]	Weight After Firing [lb (kg)]	Original Density [lb/in.^{3} (g/cm^3)]	Percent Weight Loss	Maximum Surface Recession [in. (cm)]
36 in. (91.4 cm) at 45°	Haveg 41-N	9.24 (4.19)	8.03 (3.64)	0.07 (1.83)	13.10 (13.10)	0.46 (1.17)
36 in. (91.4 cm) at 60°	Haveg 41-N	8.94 (4.06)	7.58 (3.44)	0.07 (1.83)	15.20 (15.20)	0.39 (1.00)
12 in. (30.5 cm) at 90°	Fondu-Fyre WA-1	11.20 (5.08)	9.27 (4.20)	0.07 (1.99)	68.80 (68.80)	Not Avai
	Haveg 41-N	9.24 (4.19)	7.33 (3.32)	0.07 (1.83)	20.70 (20.70)	0.60 (1.52)
	Fire Retardant FR-1	6.28 (2.85)	5.85 (2.65)	0.06 (1.55)	27.20 (27.20)	0.56 (1.42)
	MXBE-350	8.87 (4.02)		0.06 (1.69)		0.46 (1.17)
	MXBE-350	9.44 (4.28)	9.26 (4.20)	0.06 (1.80)	7.60 (7.60)	0.46 (1.18)
	93-104 w/Graphite	8.25 (3.74)	7.53 (3.42)	0.05 (1.47)	34.8** (34.80*)	Burned
	Martyte	8.94 (4.06)	7.15 (3.24)	0.05 (1.44)	80.0* (80.00*)	Burned
	HDFG (Carbon)	2.09 (0.95)	2.03 (0.92)	0.06 (1.61)	2.90 (2.90)	0.15 (0.39)
	Steel Plate	39.65 (17.98)	37.85 (17.17)	0.28 (7.84)	18.00 (18.00)	0.45 (0.14)
	93-104 w/Graphite	7.69 (3.49)	6.01 (2.73)	0.05 (1.47)	21.80* (21.80)*	Burned
	Hitco w/Refrasil	5.92 (2.68)	5.74 (2.60)	0.06 (1.61)	2.10** (2.10)	0.40 (1.01)
	FMI Carbon FR-2	8.90 (4.04)	8.47 (3.84)	0.05 (1.44)	19.20 (19.20)	0.30 (0.77)
	Pitch Fiber FMI Cast Plate FR-2	7.43 (3.37)	7.01 (3.18)	0.05 (1.36)	22.80 (22.80)	0.33 (0.83)
	Vacuum Impregnated FMI Fiber Form FR-3	6.91 (3.13)	6.41 (2.91)	0.05 (1.33)	28.90 (28.90)	0.52 (1.31)
	Haveg 41-N	9.20 (4.17)	8.77 (3.98)	0.07 (1.83)	18.80 (18.80)	0.60 (1.52)

ring Test Data; Restrained (Continued)

cm³)]	Percent Weight Loss	Maximum Surface Recession [in. (cm)]	Maximum Recession Rate [in./sec (cm/sec)]	Thermal Conductivity [Btu/ft/hr/°F (cal/sec/cm/°C)]	Comments
	13.10 (13.10)	0.46 (1.17)	0.09 (.22)	0.20 (0.84×10^{-3})	
	15.20 (15.20)	0.39 (1.00)	0.08 (0.19)	0.20 (0.84×10^{-3})	
	68.80 (68.80)	Not Available		0.33 (1.38×10^{-3})	Material was broken while being removed from plate
	20.70 (20.70)	0.60 (1.52)	0.11 (0.29)	0.20 (0.84×10^{-3})	Control sample
	27.20 (27.20)	0.56 (1.42)	0.29 (0.74)	~0.10 (0.41×10^{-3})	
		0.46 (1.17)	0.09 (0.23)	0.20 (0.83×10^{-3})	
	7.60 (7.60)	0.46 (1.18)	0.09 (0.23)	0.37 (1.53×10^{-3})	
	34.8** (34.80*)	Burned Through		0.20 (0.84×10^{-3})	
	80.0* (80.00*)	Burned Through		Not Available	
	2.90 (2.90)	0.15 (0.39)	0.03 (0.07)	85.0 (0.35)	6 x 6 in. (15.2 x 15.2 cm) sample
	18.00 (18.00)	0.45 (0.14)	0.09 (0.22)	~22 @ 32°F (0.09)	Control sample
	21.80* (21.80)*	Burned Through		0.20 ($0.84 \times 10_{-}^{3}$)	
	2.10** (2.10)	0.40 (1.01)	0.08 (0.19)	0.23 (0.96×10^{-3})	10 x 10 in. (25.4 x 25.4 cm) sample
	19.20 (19.20)	0.30 (0.77)	0.06 (0.15)	~0.10 (0.41×10^{-3})	
	22.80 (22.80)	0.33 (0.83)	0.06 (0.16)	~0.10 (0.41×10^{-3})	
	28.90 (28.90)	0.52 (1.31)	0.10 (0.25)	~0.10 (0.41×10^{-3})	
	18.80 (18.80)	0.60 (1.52)	0.11 (0.29)	0.20 (0.84×10^{-3})	Control sample

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Table 1. Firing Test Data; Restrained

Location	Material	Weight Before Firing [lb (kg)]	Weight After Firing [lb (kg)]	Original Density [lb/in.^{3} (g/cm^3)]	Percent Weight Loss	Maximum Surface Recession [in. (cm)]
	FMI 3-D Quartz	9.25 (4.19)	8.33 (3.78)	0.06 (1.61)	9.90 (9.90)	0.29 (0.73)
6 in. (15.2 cm) at 90°	Haveg 41-N	9.26 (4.20)	8.00 (3.63)	0.07 (1.83)	13.60 (13.60)	0.40 (1.02)
	Hitco w/Refrasil	6.89 (3.12)	6.29 (2.85)	0.06 (1.61)	24.20 (24.20)	0.26 (0.66)
	Fire Retardant FR-1	7.37 (3.34)	7.10 (3.22)	0.06 (1.55)	14.60 (14.60)	0.19 (0.48)
	MXBE-350	10.41 (4.72)	10.14 (4.60)	0.06 (1.69)	10.40 (10.40)	0.29 (0.74)
	MXB-360	12.00 (5.44)	11.84 (5.37)	0.07 (1.80)	5.30 (5.30)	0.23 (0.59)
	German Material w/Asbestos	17.24 (7.87)	16.03 (7.27)	0.060 (1.66)	11.00** (11.00)	0.36 (0.92)
	Fire Retardant FR-1	7.23 (3.28)	6.27 (2.84)	0.06 (1.55)	13.40 (13.40)	0.40 (1.01)
	Fire Retardant FR-1	7.32 (3.32)	6.29 (2.85)	0.06 (1.55)	14.20 (14.20)	0.40 (1.02)
6 in. (15.2 cm) at 15°	Fire Retardant FR-1	7.48 (3.39)	6.62 (3.00)	0.056 (1.55)	11.5 (11.50)	0.38 (0.97)

* Figures are based on actual weights and may be greater than indicated due to burn-through condition.
** Figures are normalized to a 12 x 12 in. (30.5 x 30.5 cm) sample (see Figure 6).

1

ring Test Data; Restrained (Continued)

cm^3)]	Percent Weight Loss	Maximum Surface Recession [in. (cm)]	Maximum Recession Rate [in./sec (cm/sec)]	Thermal Conductivity [Btu/ft/hr/°F (cal/sec/cm/°C)]	Comments
	9.90 (9.90)	0.29 (0.73)	0.05 (0.14)	0.22 (0.90 x 10^{-3})	
	13.60 (13.60)	0.40 (1.02)	0.08 (0.20)	0.20 (0.84 x 10^{-3})	Control sample
	24.20 (24.20)	0.26 (0.66)	0.05 (0.13)	0.23 (0.96 x 10^{-3})	10 x 10 in. (25.4 x 25.4 cm) sample
	14.60 (14.60)	0.19 (0.48)	0.04 (0.09)	~0.10 (0.41 x 10^{-3})	
	10.40 (10.40)	0.29 (0.74)	0.06 (0.14)	0.20 (0.83 x 10^{-3})	
	5.30 (5.30)	0.23 (0.59)	0.05 (0.11)	0.37 (1.53 x 10^{-3})	
	11.00** (11.00)	0.36 (0.92)	0.07 (0.17)	Not available	15 x 15 in. (38.1 x 38.1 cm) sample
	13.40 (13.40)	0.40 (1.01)	0.08 (0.19)	~0.10 (0.41 x 10^{-3})	Used in test with launcher tube simulator
	14.20 (14.20)	0.40 (1.02)	0.08 (0.20)	~0.10 (0.41 x 10^{-3})	
	11.5 (11.50)	0.38 (0.97)	0.07 (0.19)	~0.10 (0.41 x 10^{-3})	

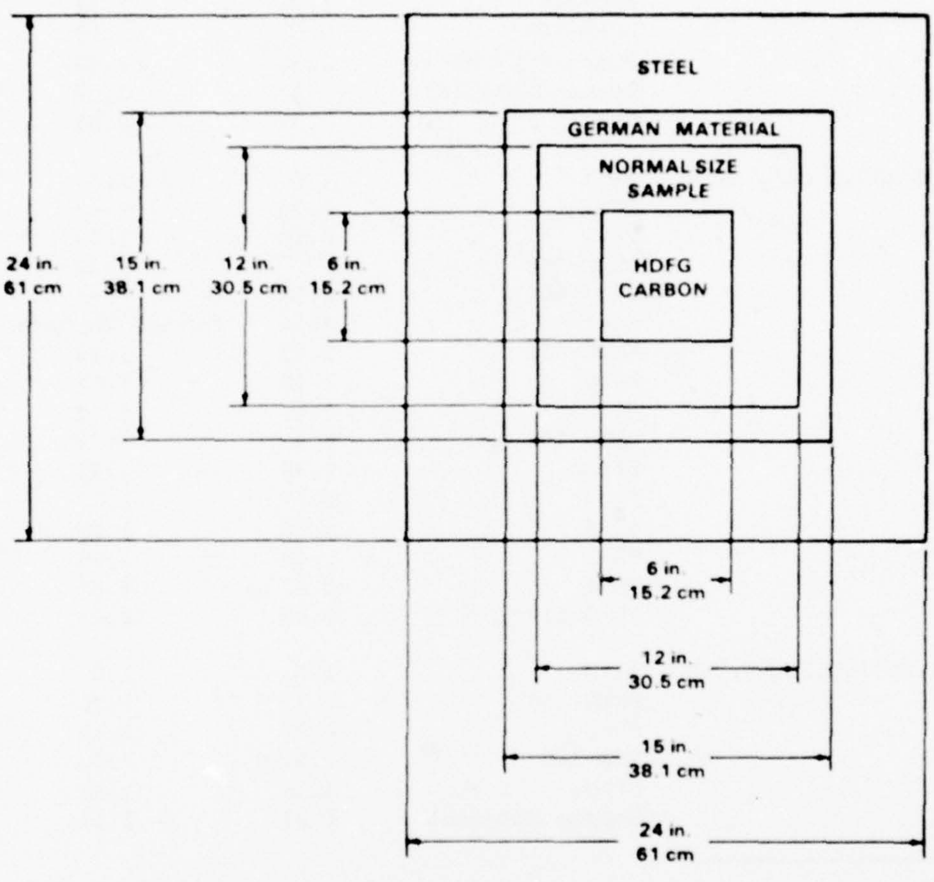
urn-through condition.

1 2

Table 2. Firing Test Data; Flyaway

Material	Weight Before Firing* [lb (kg)]	Weight After Firing* [lb (kg)]	Original Density [lb/in.^{3} (g/cm^3)]	Percent Weight Loss	Thermal Conductivity [Btu/ft/hr/°F (cal/sec/cm) °C)]	Comments
Fire Retardant FR-1			0.06 (1.55)		~0.100 (0.41 x 10^{-3})	
15°	83.56 (37.90)	83.50 (37.86)		0.07 (0.07)		
30°	83.50 (37.86)	83.63 (37.93)		0.15+ (0.15+)		
45°	83.63 (37.93)	83.75 (37.99)		0.14+ (0.14+)		
90°	83.54 (37.89)	83.56 (37.90)		0.02+ (0.02+)		
Dow Corning 93-104 w/Graphite			0.05 (1.47)		0.202 (0.84 x 10^{-3})	
15°	87.69 (39.78)	87.75 (39.80)		0.07+ (0.07)		
30°	87.75 (39.80)	87.75 (39.80)		0.00 (0.00)		
45°	87.75 (39.80)	87.44 (39.66)		0.35 (0.35)		Material was cut by separated motor nozzle
90°	87.83 (39.84)	87.69 (39.78)		0.16 (0.16)		

* Weight shown includes weight of backplate.



DUE TO VARIOUS SIZES OF AVAILABLE MATERIAL, ALL PERCENTAGES OF WEIGHT LOSS WERE NORMALIZED TO 12 in. (30.48 cm) SAMPLES FOR COMPARISON. SECTIONS WERE TAKEN FROM THE AREA OF FULL IMPINGEMENT. FIGURES SHOWN IN WEIGHT COLUMNS OF TABLE 1 ARE ACTUAL MATERIAL WEIGHTS AND ARE NOT NORMALIZED.

Figure 6. Various Sizes of Materials Tested

Table 3. Rocket Motor Mk 36 Tests

Location	Material	Relative Performance	
		Mass Loss*	Recession**
3 ft (91.4 cm), 90°	41-N (Sample 1)	1.0	1.0
	41-N (Sample 2)	0.95	1.11
	Kevlar	0.30	Burned Through
	Dynatherm	0.17	Burned Through
	FR-1	0.54	1.07
	MXBE-350	---	1.26
	MXB-360	1.28	1.11
	DC93-104	0.61	1.58
	Fondu-Fyre XB-1	1.35	1.18
	German Material	1.24	1.04
	Steel	2.01	0.91
1 ft (30.5 cm), 90°	41-N	1.0	1.0
	FFWA-1	0.30	---
	FR-1	0.76	1.07
	MXBE-350		1.30
	DC93-104	0.59	---
	Martyte	0.26	Burned Through
	MXBE-350	2.72	1.29
	HDPG	7.13	3.95
	Steel	1.15	1.34
	DC93-104	0.95	---
	Hitco	9.78	1.51
	FR-3	0.72	1.17
	41-N	1.10	1.00
	FR-2	1.08	1.98
	FR-4	0.91	1.83
	3D-Quartz	2.09	2.08
0.5 ft (15.2 cm), 90°	41-N	1.0	1.0
	MXBE-350	1.31	1.38
	FR-1	0.92	2.13
	MXB-360	2.62	1.72
	Hitco	0.56	1.55
	German Material	1.24	1.11

* Data are normalized to 12.0 x 12.0 in. (30.5 x 30.5 cm) sample.

** Values greater than 1.0 indicate better performance.

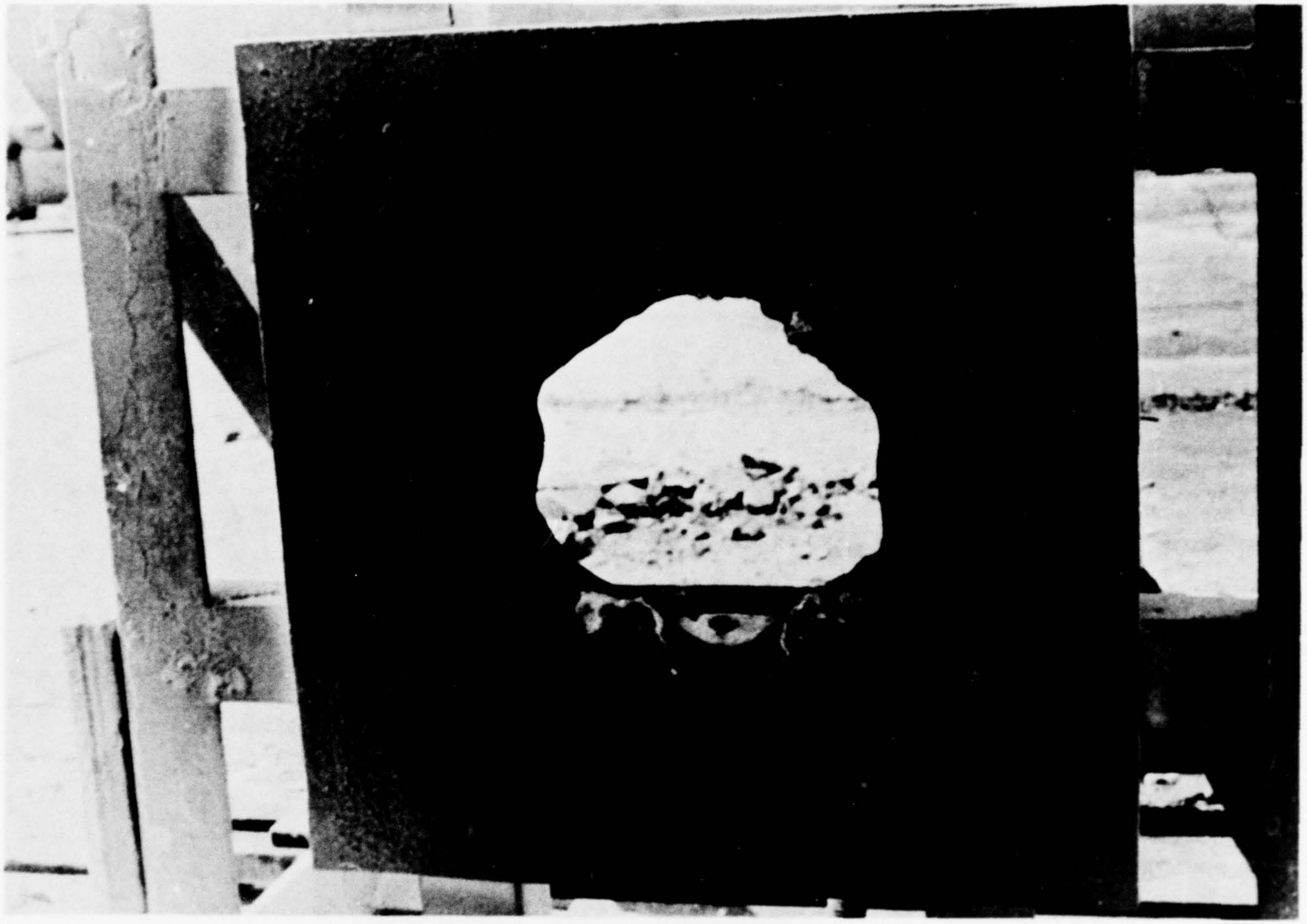


Figure 7. Aluminum Plate After Firing; 36 in. (91.4 cm) at 90°

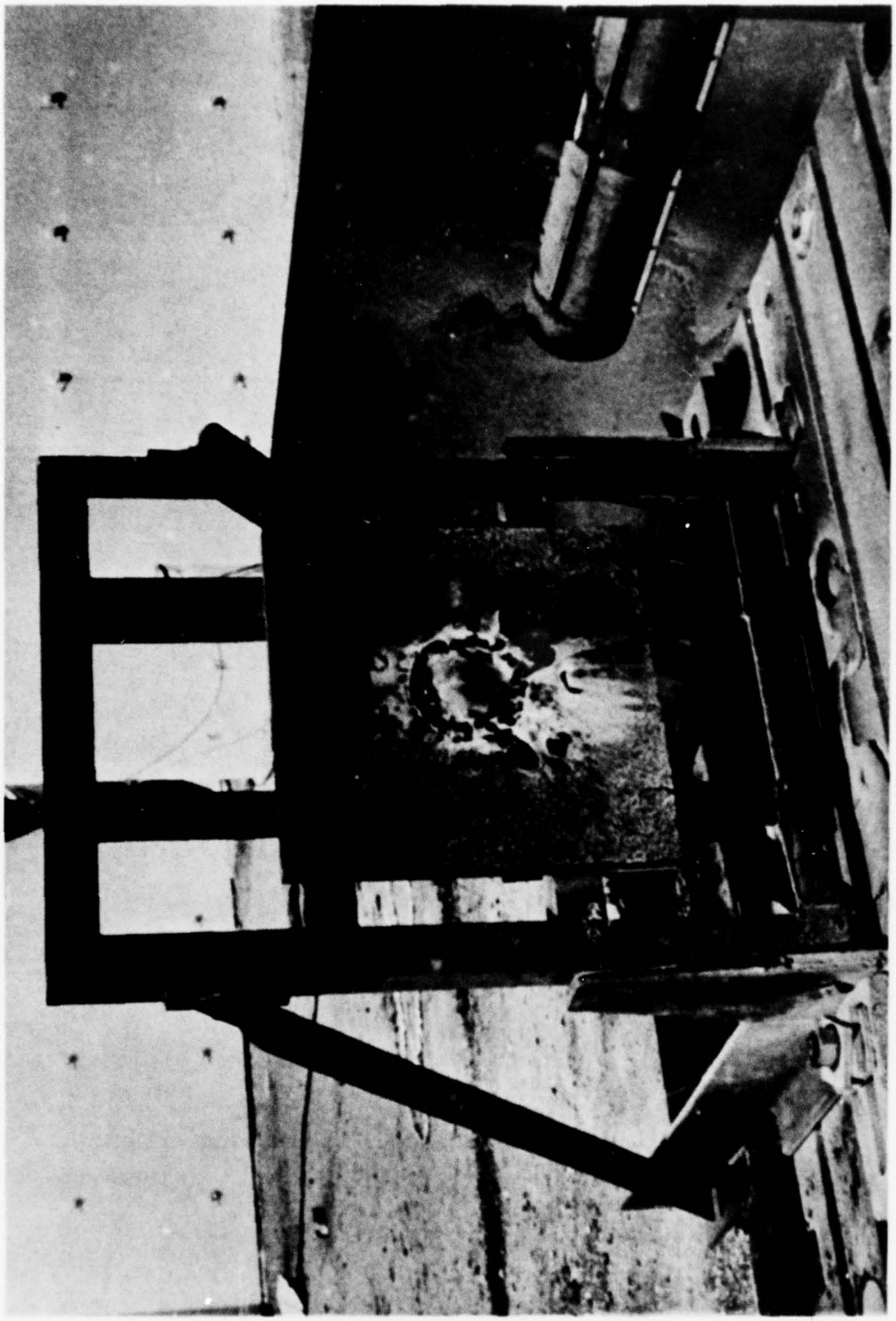


Figure 8. Steel Plate After Firing; 36 in. (91.4 cm) at 90°

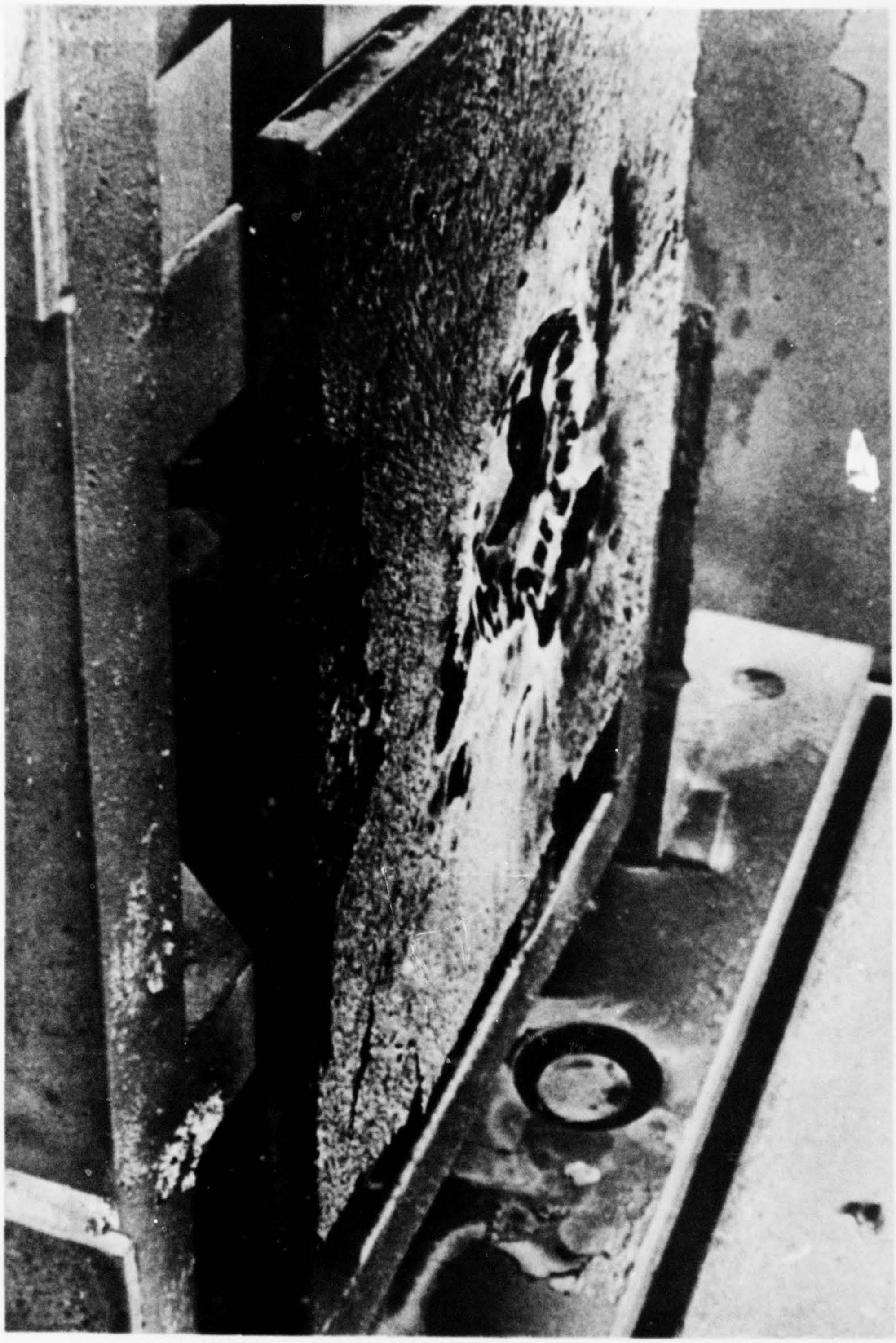


Figure 9. Steel Plate With Aluminum Oxide Coating; 36 in. (91.4 cm) at 90°

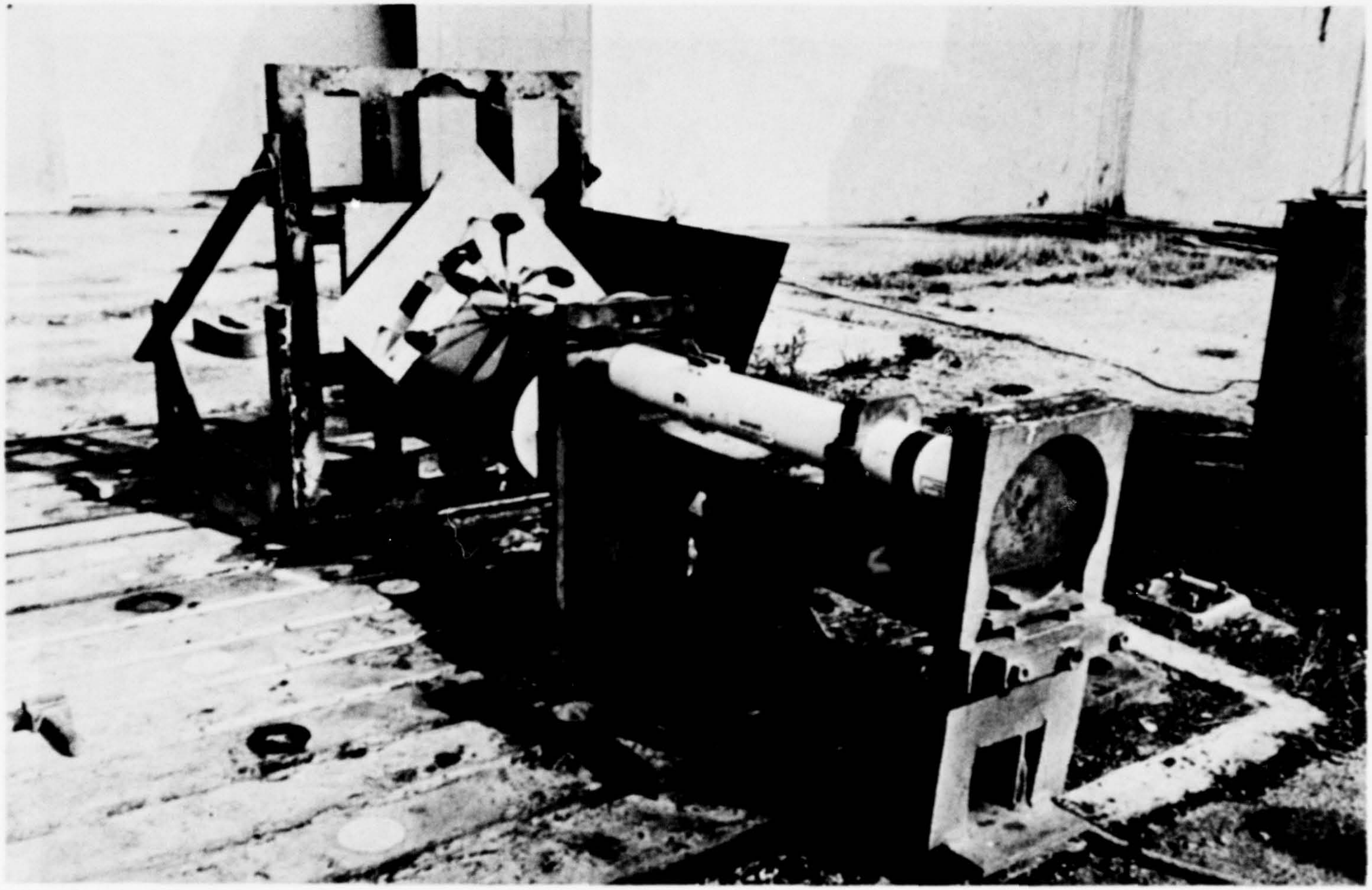


Figure 10. Simulated Launcher Tube Arrangement; 6 in. (15.2 cm) at 90°

MATERIAL CHARACTERISTICS

The materials tested and the pertinent information concerning each follow:

1. Haveg 41-N; Haveg Industries Inc., Wilmington, Delaware

Haveg 41-N is a Silica-filled cast phenolic composition that has the thermal characteristics of an insulator. Haveg 41-N was developed as a replacement for Haveg 41 (which contained asbestos). It produced a charred effect when exposed to a rocket motor blast and exhibited a very low ablation rate in the tests performed. This material is very hard, and it is available only in preformed sections.

2. MXB-360; Fibrite Corp., Winona, Minnesota

MXB-360 is a phenolic resin material that contains silica filler and is reinforced by continuous strand, random oriented, E-glass fiber mat. It has the thermal characteristics of an insulator. This material produced a charred effect when exposed to a rocket motor blast and showed a very low ablation rate in all phases of the test. It is a very hard material, is difficult to machine, and is available only in preformed sections.

3. MXBE-350; Fibrite Corp., Winona, Minnesota

MXBE-350, a spin-off of MXB-360, is a rubber-modified glass phenolic material. It exhibits the thermal characteristics of an insulator and showed a moderate ablation rate during the rocket motor burn. This material is also very hard (even though rubber-modified) and is difficult to machine. It is available only in preformed sections.

4. FR-1; Fiber Materials Inc., Biddeford, Maine

FR-1 (fire retardant) is an ablative material and is composed of silica and phenolic resin. The material is also available with carbon fiber (designated FR-2 in this report). It acts as an insulator and produced a charred effect when exposed to a rocket motor blast. This material showed a relatively low ablation rate in the test performed. It is available in preformed sections, in a mixture that can be troweled onto a roughened surface, and in a rigid foam.

5. FR-2; Fiber Materials Inc., Biddeford, Maine

FR-2 contains carbon fibers in lieu of the silica in FR-1. It is an ablative material and acts as an insulator. It produced a charred effect when exposed to a rocket motor blast. This material is available in preformed sections; in a mixture that can be troweled onto a roughened surface, and in a rigid foam.

6. FR-3; Fiber Materials, Inc., Biddeford, Maine

FR-3 is composed of carbon fiber preform, is resin impregnated, and is vacuum cast. It is an ablative material and acts as an insulator. This material showed a relatively low ablation rate and is available only in preformed panels.

7. HDFG; Fiber Materials Inc., Biddeford, Maine

HDFG is a carbon/carbon composition with the thermal characteristics of a conductor. It is a subliming type of material and showed a very low sublimation rate when exposed to the rocket motor blast. However, the heat transfer coefficient is high and the temperature rise at the material-backplate interface is undesirable in this application.

8. 3-D Quartz; Fiber Materials Inc., Biddeford, Maine

3-D Quartz is a three-dimensional quartz filament weave impregnated with phenolic resin. It is a melting type ablative material and has the thermal characteristics of an insulator. It showed a very low ablation rate when exposed to a rocket motor blast. The material is very hard and is available only in preformed sections.

9. Martyte; Presstite Products, Inmot Corp., St. Louis, Missouri

Martyte is an epoxy cured resin filled with dried silica, and it can be applied by pouring or troweling. It has the thermal characteristics of an insulator and exhibited a high ablation rate when exposed to a direct rocket motor burn.

10. Kevlar; E. I. DuPont de Nemours & Company

The material tested is an ablative material containing Kevlar 29 cloth with Derakane 510A40 resin, 22 percent by weight. This material acts as an insulator and showed a high ablation rate with a charred effect during exposure to a direct rocket motor burn.

11. Hitco w/Refrasil; Hitco, Defense Products Division, Gardenia, California

The material tested contained 30 to 36 percent resin by weight, 3.3 percent volatile components, and laminated Refrasil cloth (the Refrasil cloth is a refractory silica in textile form). It is an insulator and had a very low ablation rate during the rocket motor impingement; however, some delamination occurred when brought into close proximity to the rocket motor nozzle. This material (as tested) is available only in preformed sections, is very hard and, is difficult to machine.

12. WA-1 (Fondu-Fyre); Designed Concretes Co., Santa Fe Springs, California

This is an ablative concrete type of material and acts as an insulator. It ablates by a melting process and has a medium ablation rate. WA-1

is normally used as a base for the XB-1 top coat. Fondu-Fyre can be applied by normal concrete application methods.

13. XB-1 (Fondu-Fyre); Designed Concretes Co., Santa Fe Springs, California

This material is normally used as a top coat for the WA-1 and performs as an insulator. This coating also ablates by a melting process and showed a low ablation rate. It can be applied and smoothed with a trowel or float.

14. Dynatherm E-340; Flamemaster Corp., Sun Valley, California

On recommendation from the manufacturer, E-340 was used in lieu of the E-320, which was selected as a result of the intial screening, because of the unfavorable weathering characteristics of E-320. E-340 is a two-part epoxy-based composition with the thermal characteristics of an insulator. E-340 proved to have a high ablation rate when exposed to the rocket motor blast. It can be purchased in preformed sections or in a mixture to be troweled on.

15. DC93-104; Dow Corning Corp., Midland, Michigan

DC93-104 is composed of silicone rubber with graphite fibers as a filler. It exhibited a charred effect when exposed to a rocket motor blast. This material is an insulator and showed a moderately high rate of ablation when exposed to the direct impingement of the rocket motor blast. It is a flexible material and can be troweled or sprayed on. A primer is recommended prior to application to promote better adhesion.

CONCLUSIONS

By the program's design, a process of elimination was employed to select four ablative materials for more extensive evaluation. The materials selected were HAVEG 41-N, Fiber Materials Inc. FR-1, Fiberite Corp. MXB-360, and Dow Corning 93-104 with graphite fibers. These materials were subjected to a series of rocket motor impingement tests, which included various impingement angles and distances from the rocket motor nozzle during restrained rocket motor burning and flyaway conditions. Data were collected relative to pressure on the front face, temperature of the material on the back face, overall material lost, and depth of the maximum penetration into the sample. These data were used to evaluate whether any one or more of these samples were superior to the rest. An additional set of criteria was used to evaluate these four candidate materials: ease and cost of application, ease of repair, weight, and cost per pound. The results of this evaluation are given in Table 4.

Table 4. Evaluation of Phase III Candidates

Material	Maximum Recession Depth (X 10)*	Weight (X 2)*	Cost Per Pound (X 4)*	Ease and Cost of Application (X 8)*	Ease of Repair	Normalized Total
Haveg 41-N	10	8	10	3	See note 3	180
Fiber Materials FR-1	10	10	5	10	See note 3	220
Fibertite MXB-360	10	8	8	3	See note 3	172
Dow Corning 93-104	6	10	6	10	See note 3	184

* Normalizing Factor - The authors considered the importance of the various evaluation factors to be unequal in value; thus, a normalizing factor of "relative importance" was assigned to each of the evaluation factors to achieve a normalized total.

NOTE: EVALUATION FACTORS

1. Although "ease and cost of application" is somewhat subjective and dependent on later proven techniques and usage, it has been evaluated, relatively, along with the other comparison factors on a scale of 0 to 10 with 10 being the best or most desirable.

2. As both 41-N and MXB-360 are molded under pressure and elevated temperature, special molding dies will be required to fabricate the sections to be cemented to the carriage base ring. A simple mold-in-place procedure is described in the RECOMMENDATION section of this report for fabrication of the FR-1 sections. This factor was considered in the evaluation of "ease and cost of application".

3. Any of the materials can be repaired, at least on a temporary basis, with 93-104; and 41N, FR-1, and MXB-360 can be repaired on a relatively permanent basis with FR-1. Thus, the values assigned for "ease of repair" are considered equal for all four materials.

A subsequent series of tests will be run, and will be documented when completed, to evaluate these four materials relative to their behavior when subjected to the rigors of topside shipboard exposure (i.e., sun, salt water, cold, traffic, shock, vibration, etc.).

RECOMMENDATIONS

As the result of the testing program described herein, it is evident that there is too little difference in the ablative properties of 41-N, FR-1, or MXB-360 to warrant recommending any one of the three materials over the other two. However, because of resiliency after curing, ease and cost of application, and ease of repair, FR-1 appears to be the most promising for the solution to the blast impingement problem on the carriage base ring. On the basis of the high recession rate of the 93-104 material during restrained and flyaway rocket motor blast, it would rank last for protection of the base ring; however, resiliency after curing, ease and cost of application,

and ease of repair factors of the 93-104 material placed it number one as a recommendation for solving the reflective energy problem on the back end of the guide and the aft canister closure and for the direct blast impingement on the forward canister closure.

Two samples were selected for flyaway firing tests: FR-1 and 93-104. [Figure 5 shows a Guided Missile LAU-3A Launcher mounted to a fixture that allows the Mk 36 rocket motor (ballasted to simulate the RAM missile) to achieve free flight in simulation of a launch from the RAM launcher.] Each sample received the blast from four rocket motors at four different angles; thus, a fair representation of flyaway conditions was evaluated.

The 93-104 material sustained rather serious recession from the four blast tests (see page A-17). Subsequent examination of the data showed that (1) because of rocket motor nozzle failure, the blast erosion was not as severe as it would have been if the nozzles had not failed and (2) the impact of at least one piece of rocket motor nozzle caused accelerated recession in local areas of the material.

The FR-1 material showed so little recession after each of the four shots that no measurements were taken; however, the samples were weighed after each shot. After the first shot, the recession weight loss was less than the weight gained by deposition of Al_2O_3. It is believed that because Haveg 41-N, MXB-360, and FR-1 performed similarly during the restrained rocket motor tests, they would also perform in a similar fashion during flyaway rocket motor tests. Consequently, the flyaway tests were not duplicated for Haveg 41-N and MXB-360.

The following factors were considered in the recommendation of the FR-1 material:

1. After curing, the FR-1 material is considerably more resilient than either 41-N or MXB-360. This property gives it a better capability to withstand accidental impacts of tools, loader dollies, loader beams, etc.

   Note: During the flyaway test series, rocket motors with previously fired nozzles were used. At least one nozzle broke during the firing series and a piece of the nozzle weighing 1-3/4 lb impacted the FR-1 material causing *only superficial* damage.

2. Although 41-N and MXB-360 must be pressure and temperature molded, FR-1 can be pot mixed and troweled in place with no special tools or special troweling techniques. Repairs to FR-1 can be made with the same mixing, general purpose tools, and troweling techniques.

   Note: Because of the simple mixing and troweling requirements for application of FR-1, the following procedure is noted as a possibility for application of the FR-1 material to the base ring of the RAM launcher:

a. Spray surface to be protected with a release agent
b. Trowel FR-1 on to the desired thickness
c. Allow FR-1 to cure to a rubbery consistency
d. Score or cut though the FR-1 material to the base casting into manageable-sized sections
e. Allow FR-1 to cure completely
f. Separate cured sections from base
g. Clean release agent from base and sections
h. Apply silicone adhesive to casting
i. Place sections in original positions and weight them until adhesive is set
j. Remove weights and fill joints between sections with FR-1 or 93-104

This application technique, which has been discussed with the Fiber Materials representative, provides a resilient interface between the base ring casting and the FR-1 to allow for any differential movement due to different coefficients of expansion of FR-1 and the aluminum base ring casting. The Fiber Materials representative indicated that a primer could be developed that would increase the affinity of FR-1 to aluminum; however, use of the silicon adhesive provides a much better bond and takes care of the differential in expansion coefficients.

There is little doubt that, in addition to blast protection for LS EX 43, the same type of protection will be necessary for ship's structure and ancillary gear in close proximity to the launcher. This is especially true in the case of the Federal Republic of Germany's (FRG's) Fast Patrol Boat (FPB). Only general information is available relative to FRG's F122 Frigate and FPB class vessels. Consequently, no specific recommendations will be made in this report relative to shipboard application. It is considered pertinent to indicate that the four ablative materials subjected to the final series of tests are, in general, the best in their class of those tested at NSWC. Therefore, they should be likely candidates for shipboard application.

A sample of FR-2 was tested using the Mk 36 rocket motor at a 1 ft and 90° impingement. No other firing tests were run against the FR-2 material. The primary difference between FR-1 and FR-2 is the filler material. FR-1 contains silicon fibers, whereas FR-2 contains carbon fibers. The mass loss and erosion depth experienced in the FR-2 sample shows an appreciable improvement over the FR-1 samples tested. However, as time did not permit additional firing tests of the FR-2 material, a firm recommendation for this material cannot be made at this time. It is believed that the FR-2 material is better than the FR-1 material; however, additional testing will be required to substantiate this position. FR-2 is about 5 lb/ft^3 lighter than FR-1 and is somewhat cheaper; thus, if the additional ablative capability is desired, further testing should be done.

Material cost was one of the prime factors used in the original selection of candidate materials, as was the elimination of any material containing asbestos. There could be many more exotic materials and some containing asbestos in their make-up; however, the original premise established in the selection of the candidate materials eliminated those from the competition.

It will be noted that two samples containing a high percentage of asbestos were tested. These samples were furnished by FRG, but are not recommended for use for LS EX 43. The results of these tests are included in the body of this report and, in general, are comparable to 41-N, FR-1, and MXB-360.

NEW MATERIALS

The materials listed below have been brought to the attention of the authors by Fiber Materials Inc. (FMI). No testing of these materials has been done by NSWC; however, if the claims made by FMI can be substantiated by test, consideration could be given to their use in reducing the effects of rocket motor blast in many areas of the launcher, ship, and ancillary gear adjacent to the launcher. These are experimental materials that should be test evaluated before introduction into the RAM program. No material search has been conducted to look for competitive or similar materials.

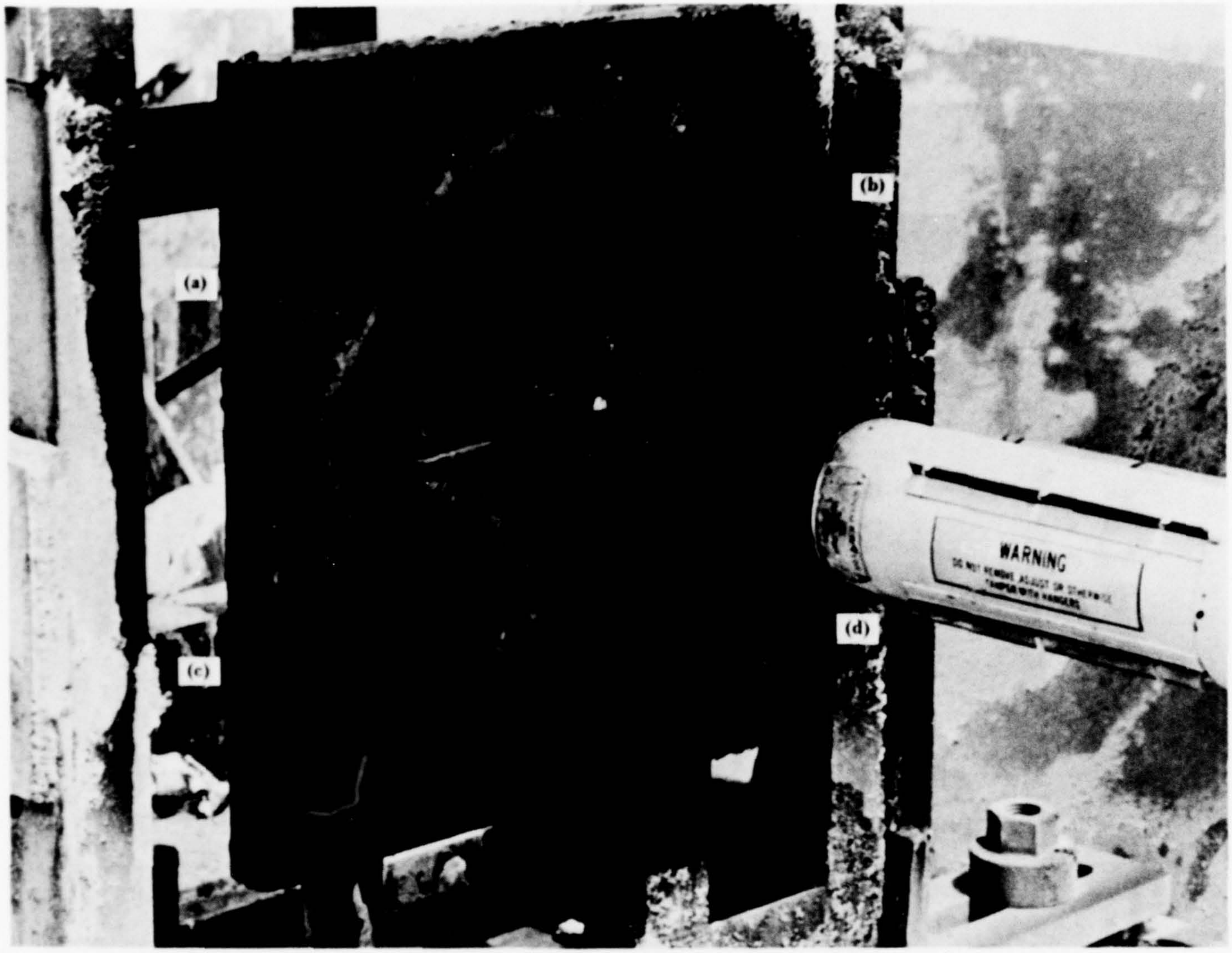
1. Fire Retardant Foam--This material can be made in practically any density from 1.8 to 2.8 lb/ft^3 and would probably be a candidate for a filler material between the guide tubes and forward and aft canister closures. This is not a completely closed cell material and as such could pickup moisture if not encapsulated or otherwise sealed.

2. Fire Retardant Resin--This is the same resin used in the manufacture of the FR-1 ablative material and can be used to paint structural material such as steel or aluminum. It would probably be an excellent undercoat for those surfaces on the launcher not protected with ablative material, but which could be subjected to blast splash. Consideration could be given to use of this material on the back end of the guide if complete protection from a restrained rocket motor is not provided.

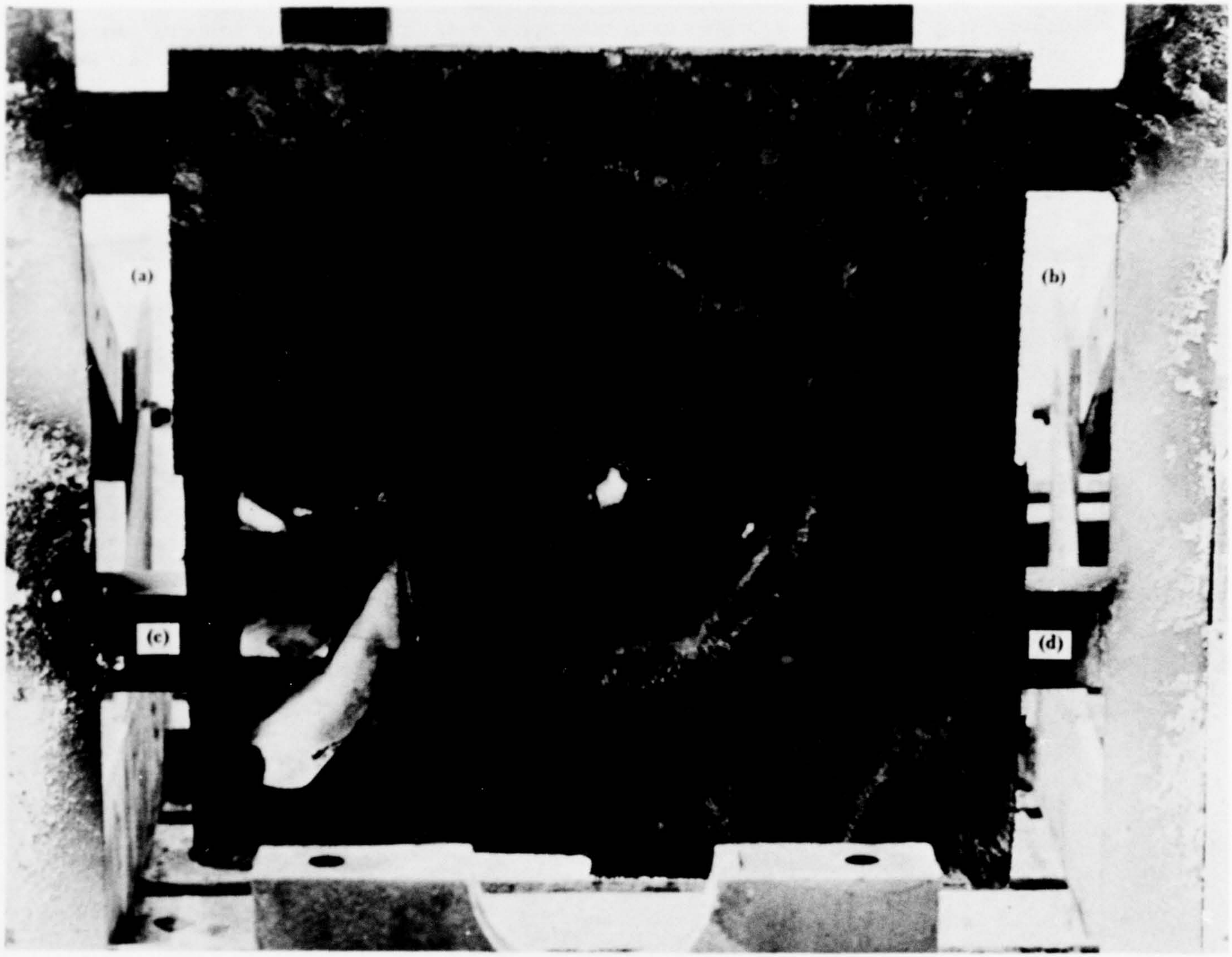
This same resin has been used in the fabrication of laminated composites by FMI. They indicated that the laminate samples shown had not been optimized for strength, but they were sure that comparable results to resins now in use could be achieved if the need were generated. This resin could probably be used to advantage, if the claims can be supported, in the layup of the canister and guide structure.

APPENDIX A

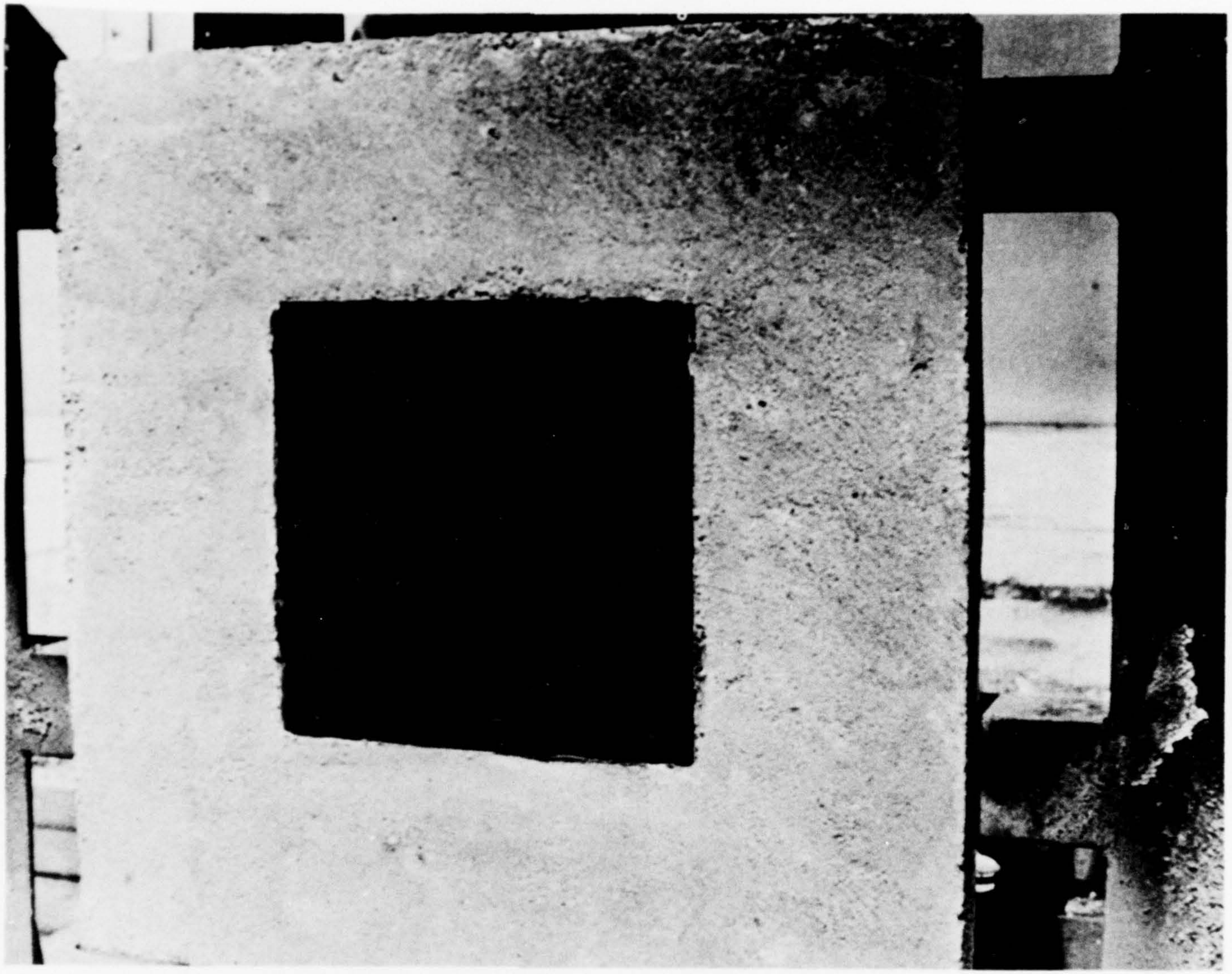
SELECTED MATERIALS, BEFORE AND AFTER FIRINGS



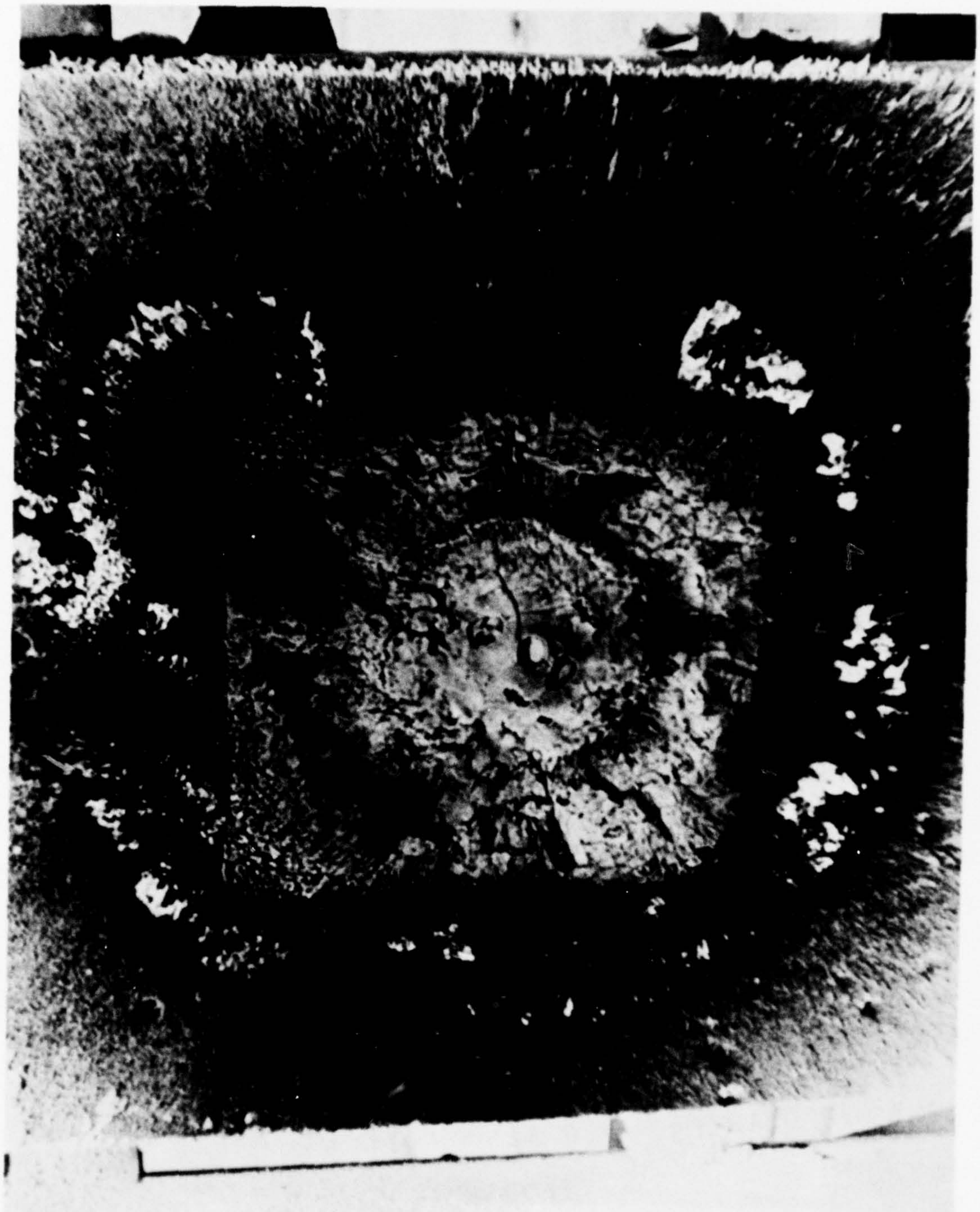
(a) Fire Retardant With Carbon Fibers FR-2, (b) Haveg 41-N, (c) Fire Retardant Fiber Preform FR-3, and (d) Fire Retardant With Carbon Fibers FR-4 (Different Resin Density Than FR-1); 12 in. (30.5 cm) at 90°



(a) MXB-360, (b) Fire Retardant FR-1, (c) Hitco with Refrasil, and (d) MXBE-350; 6 in. (15.2 cm) at 90°



Dow Corning 93-104 With Graphite (Surrounded by Fondu-Fyre for Plate Protection); 12 in. (30.5 cm) at 90°

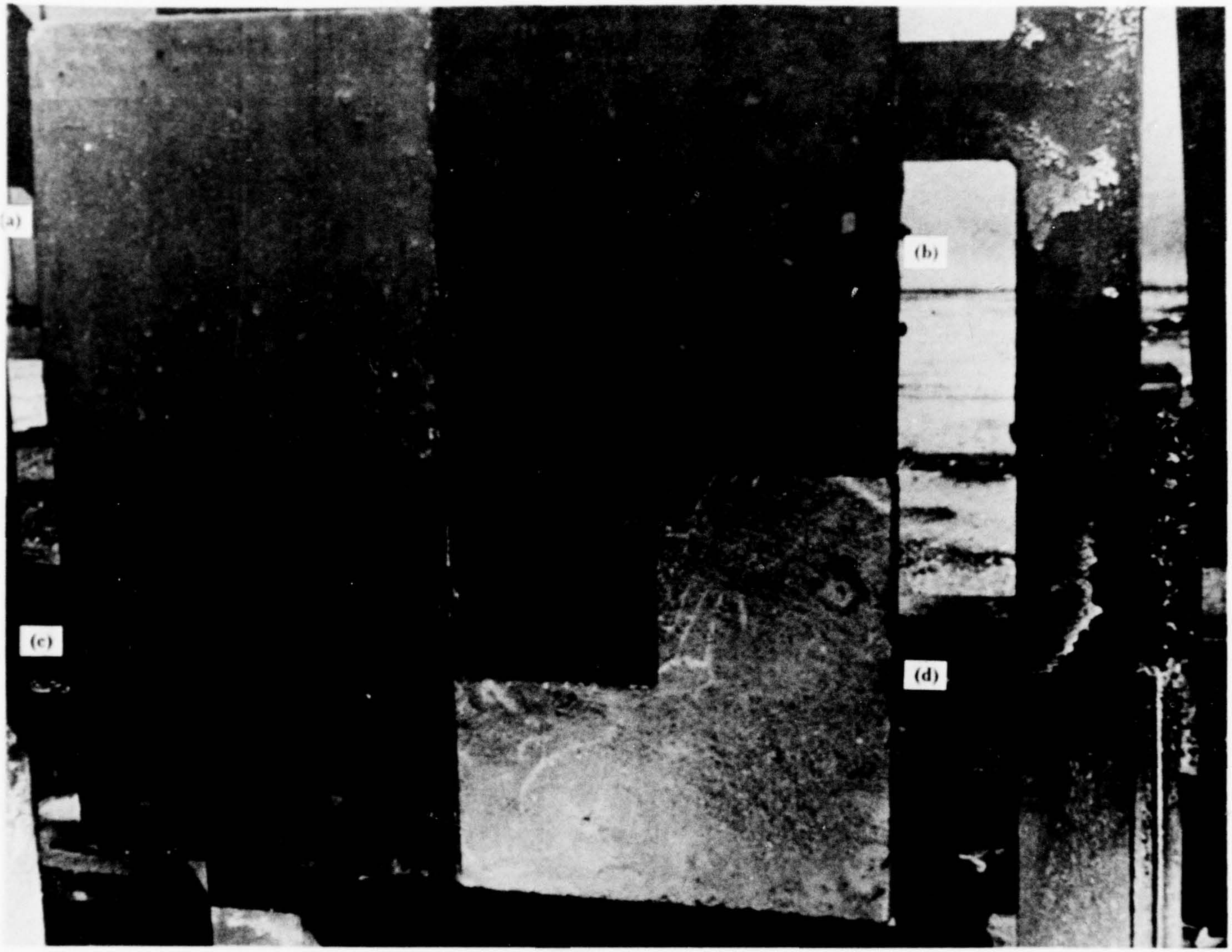


Dow Corning (After Firing) 93-104 With Graphite; 12 in. (30.5 cm) at 90°

Haveg 41-N; 12 in. (30.5 cm) at 90°

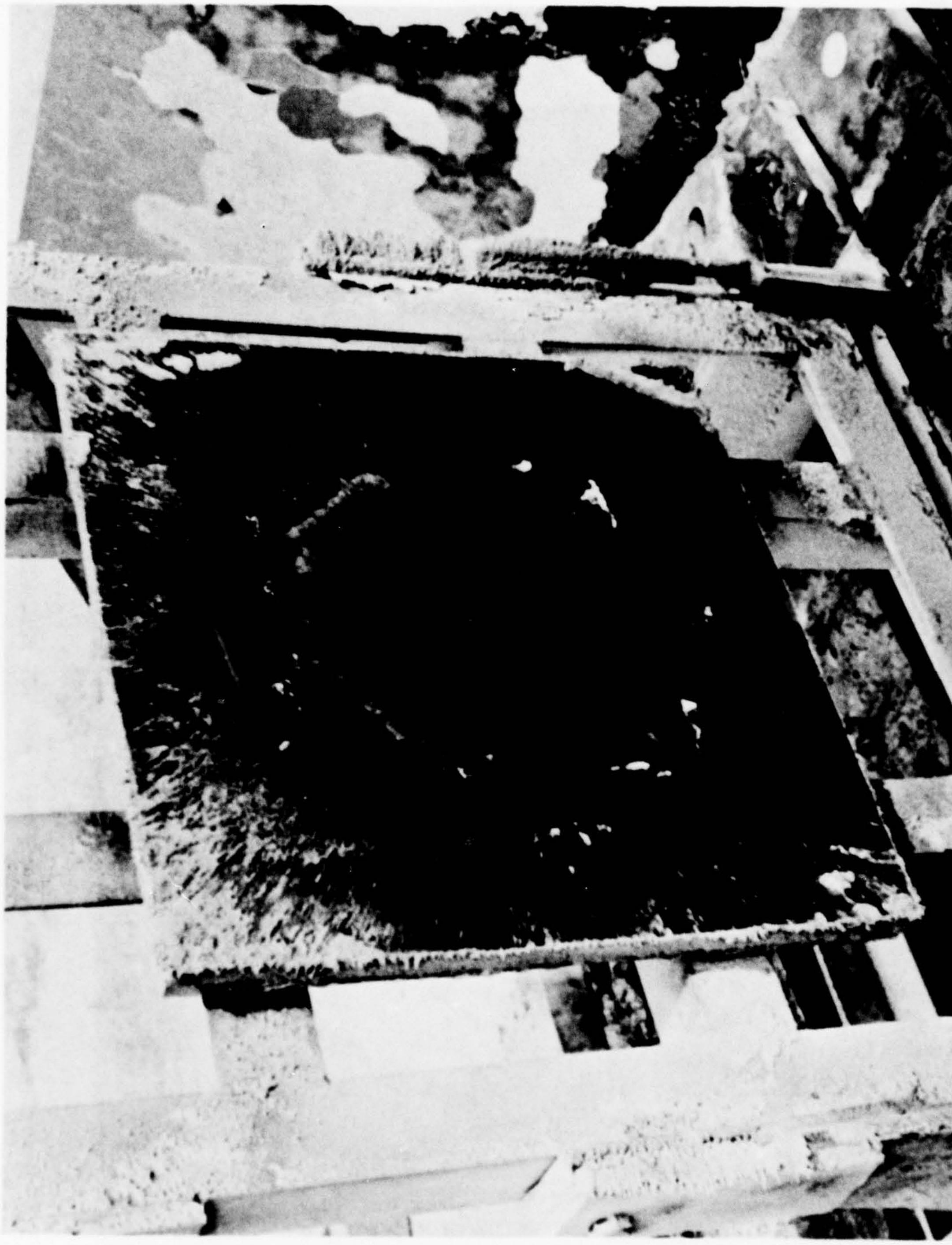
(a) Dow Corning 93-104 With Graphite and (b) Fire Retardant FR-1; 36 in. (91.4 cm) at 32.5°

Dow Corning (Single Sample) 93-104 With Graphite; 36 in. (91.4 cm) at 32.5°

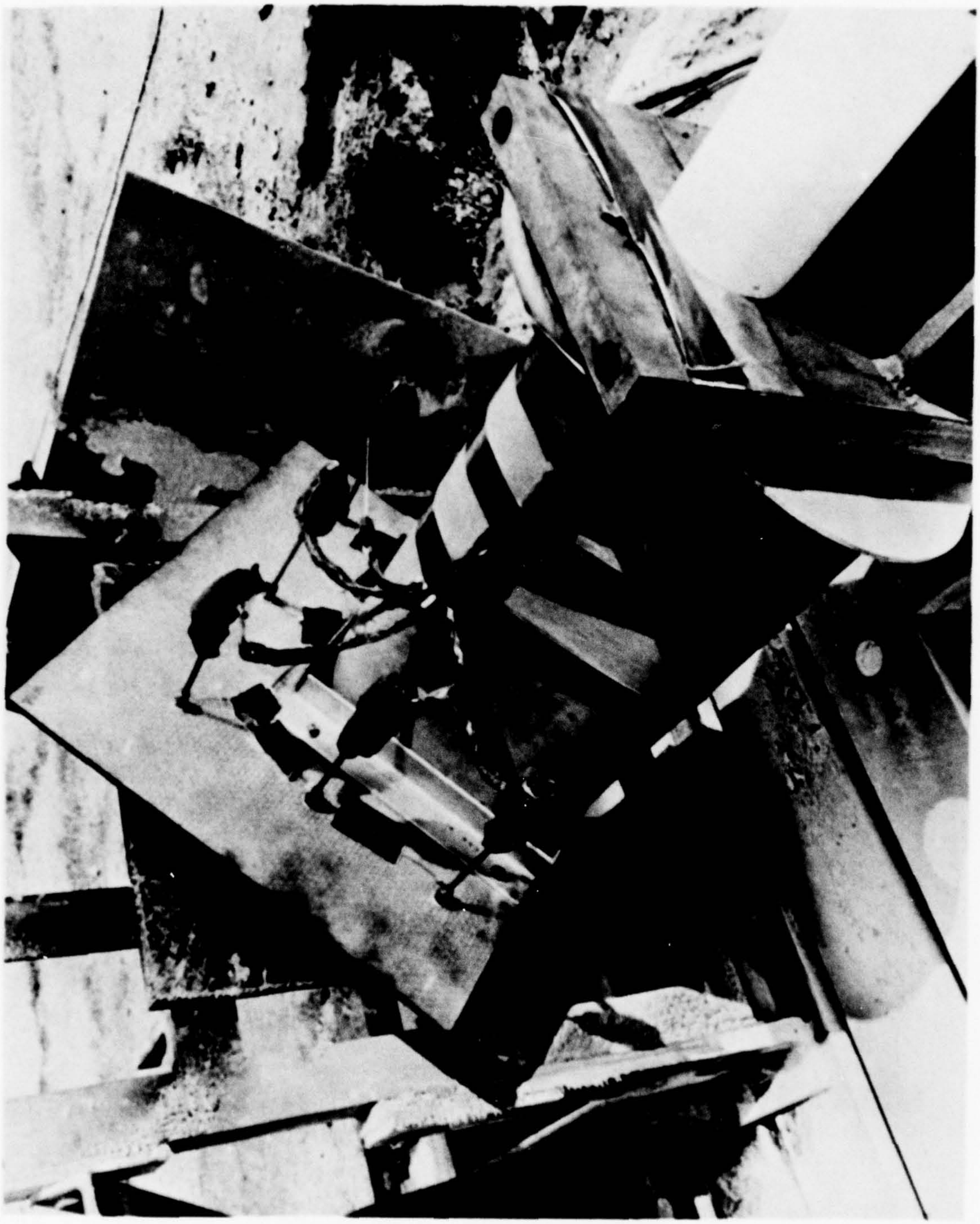


(a) Martyte, (b) MXB-360, (c) Steel, and (d) HDFG (Carbon) FMI; 12 in. (30.5 cm) at 90°

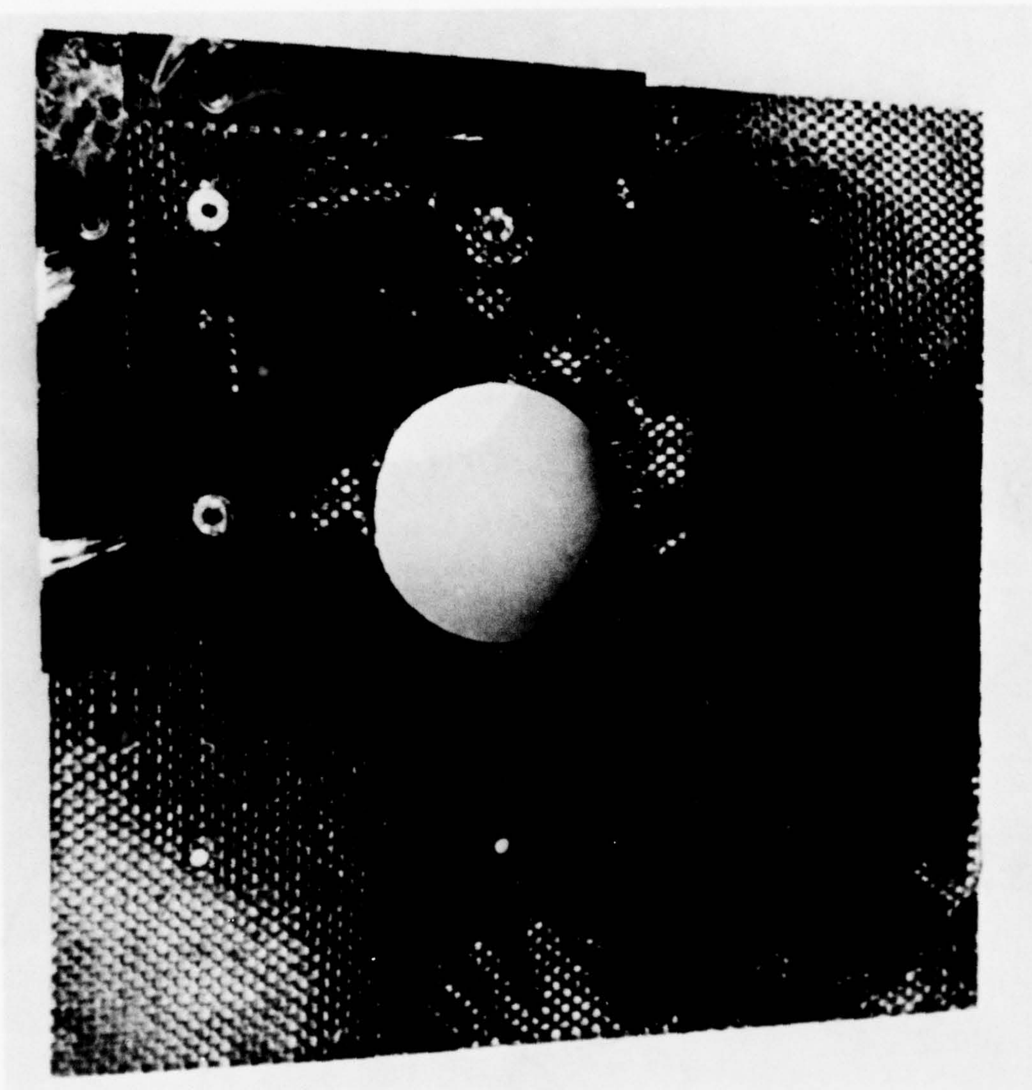
(a) Martyte, (b) MXB-360, (c) Steel, and (d) HDFG (Carbon) FMI; 12 in. (30.5 cm) at 90°



Fire Retardant FR-1; 6 in. (15.2 cm) at 90°



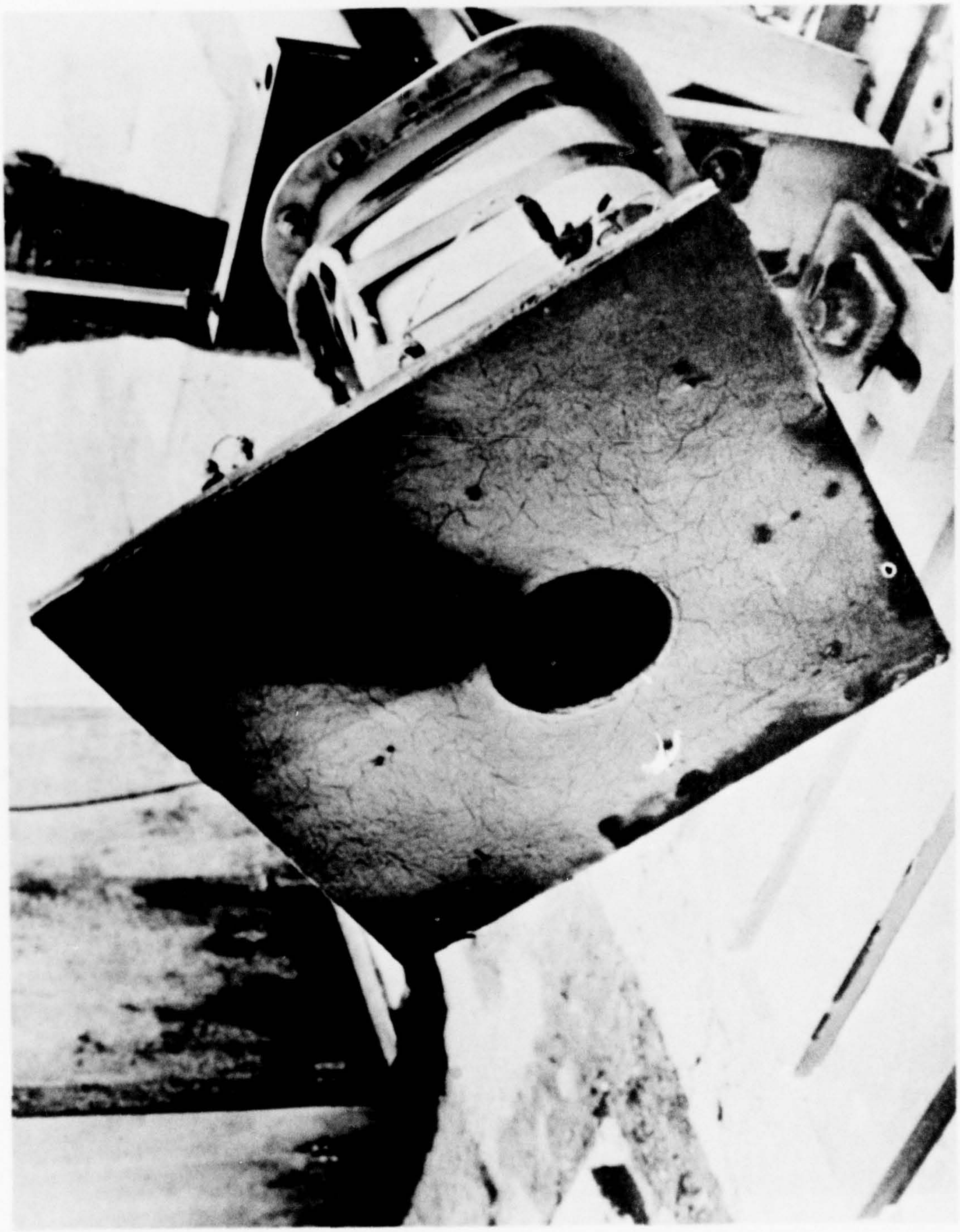
Launcher Tube Simulation (Close-Up); 6 in. (15.2 cm) at 90°



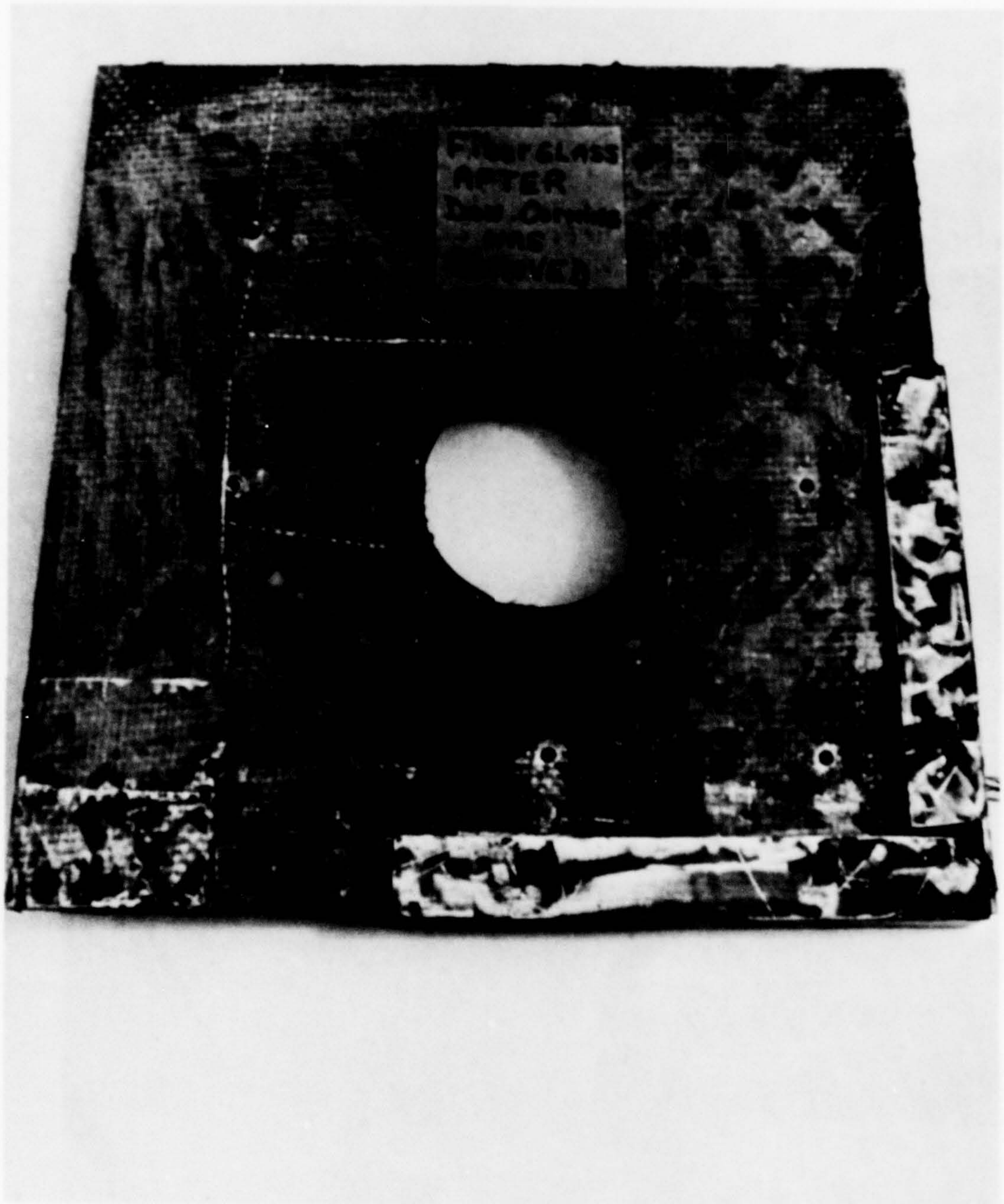
Launcher Tube Simulation Test Showing Fiberglass Plate Without 93-104 Protection; 6 in. (15.2 cm) at 90°

Fiberglass Plate (Of Launcher Tube Simulation Test) Showing Hand Removal of First Layer of Char

Fiberglass Plate (Of Launcher Tube Simulation Test) Showing Hand Removal Of Second Layer of Char



Fiberglass Plate With Approximately 1/4-in.-Thick 93-104 Protective Coating (After Firing); 6 in. (15.2 cm) at 90°

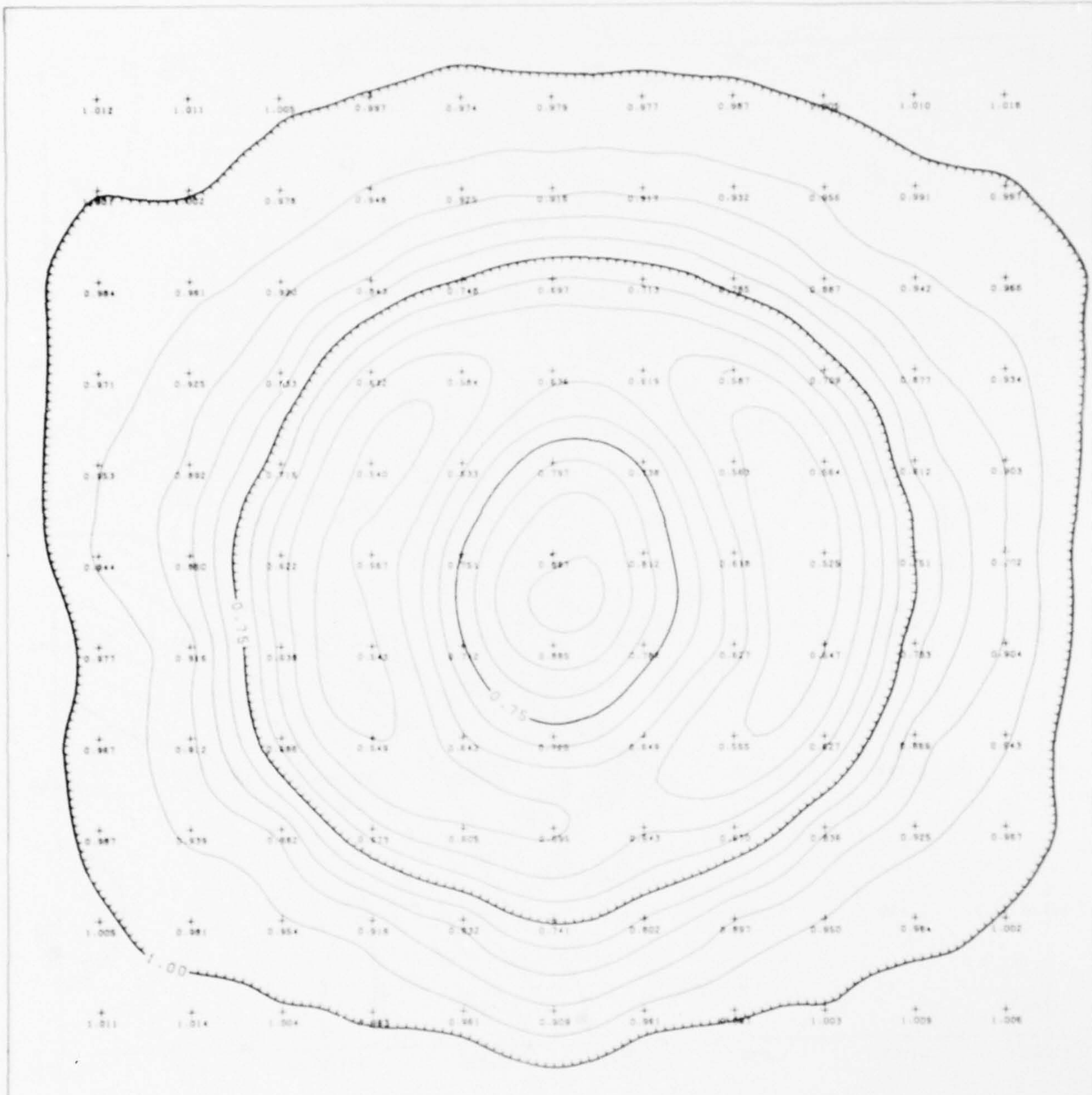


Fiberglass Plate After Removal of 93-104 Material (No Damage to Protected Portion of Plate)

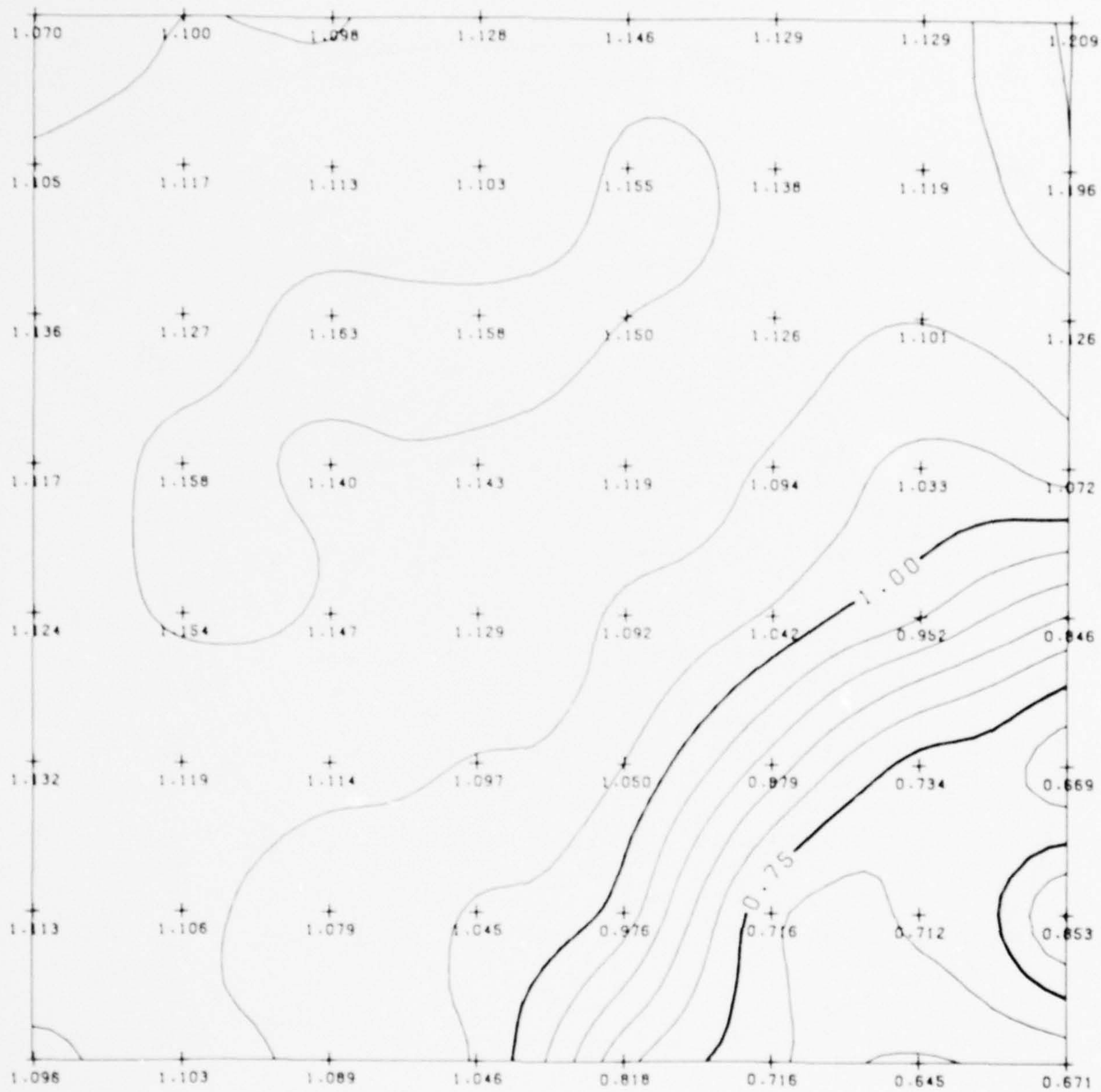
Dowing Corning Material (93-104) After Flyaway Firings

APPENDIX B

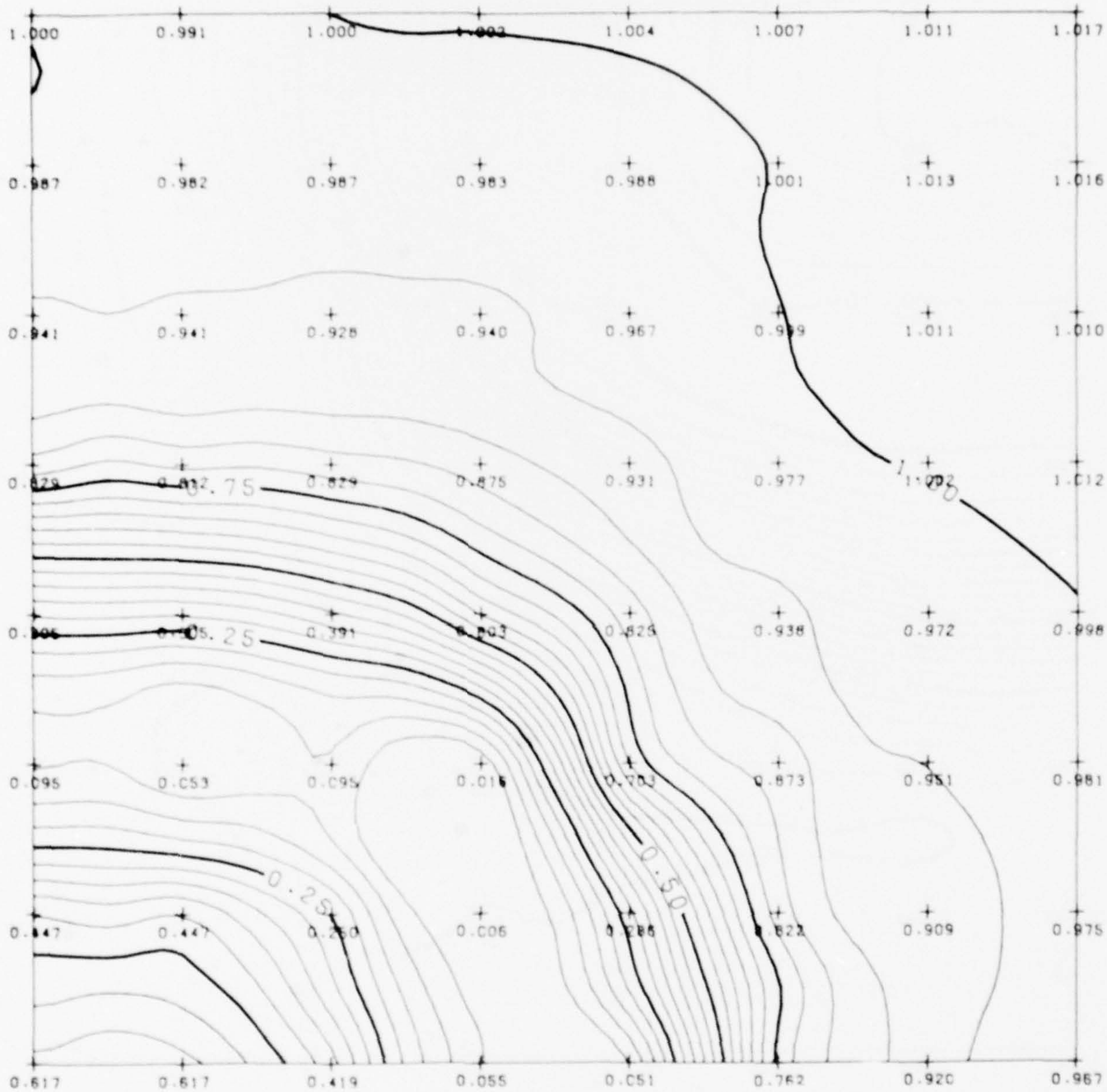
CONTOUR PLOTS OF ABLATIVE MATERIAL RESULTS



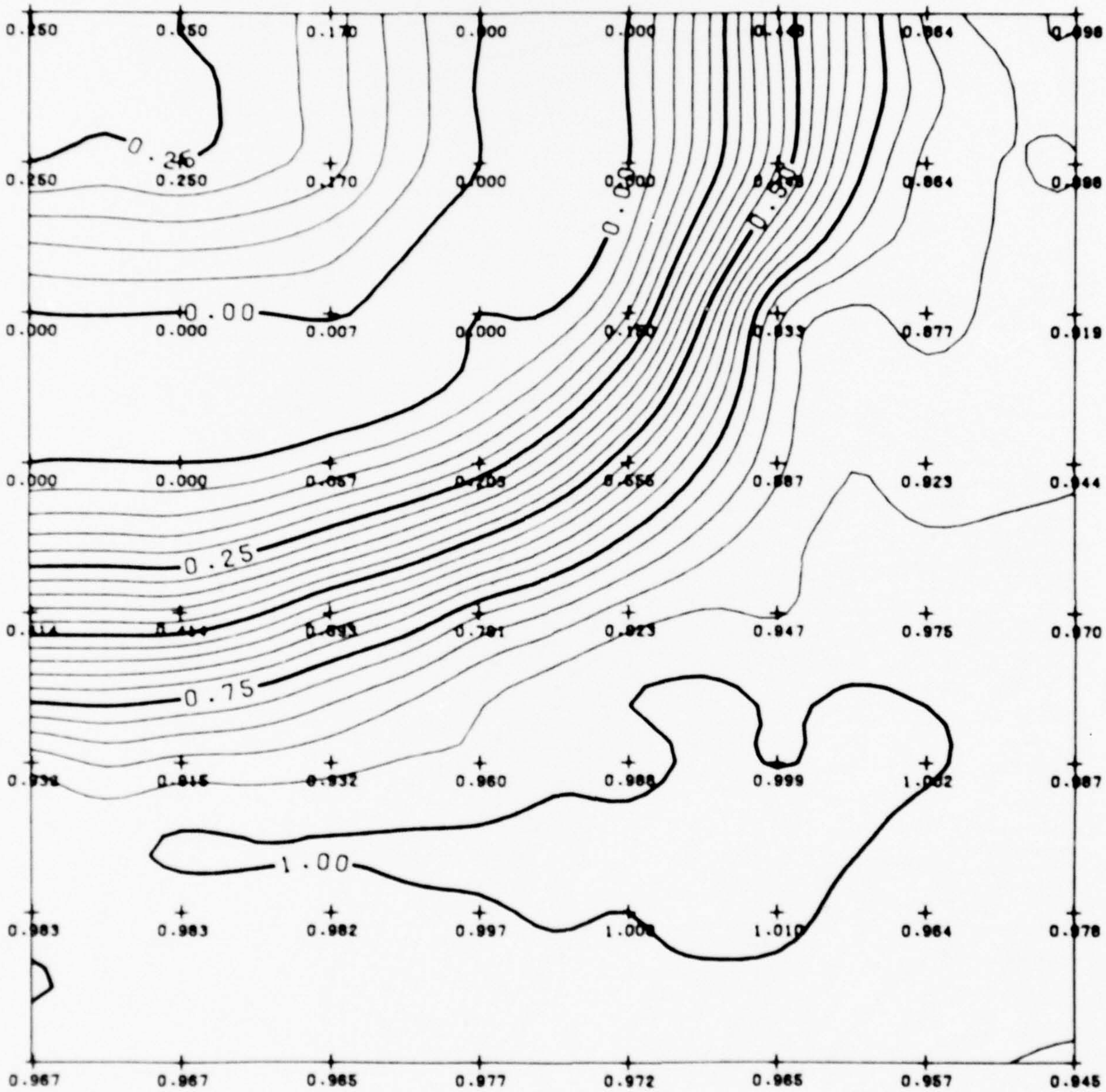
Haveg 41-N; 90° 3 Ft, Rocket Motor Mk 36



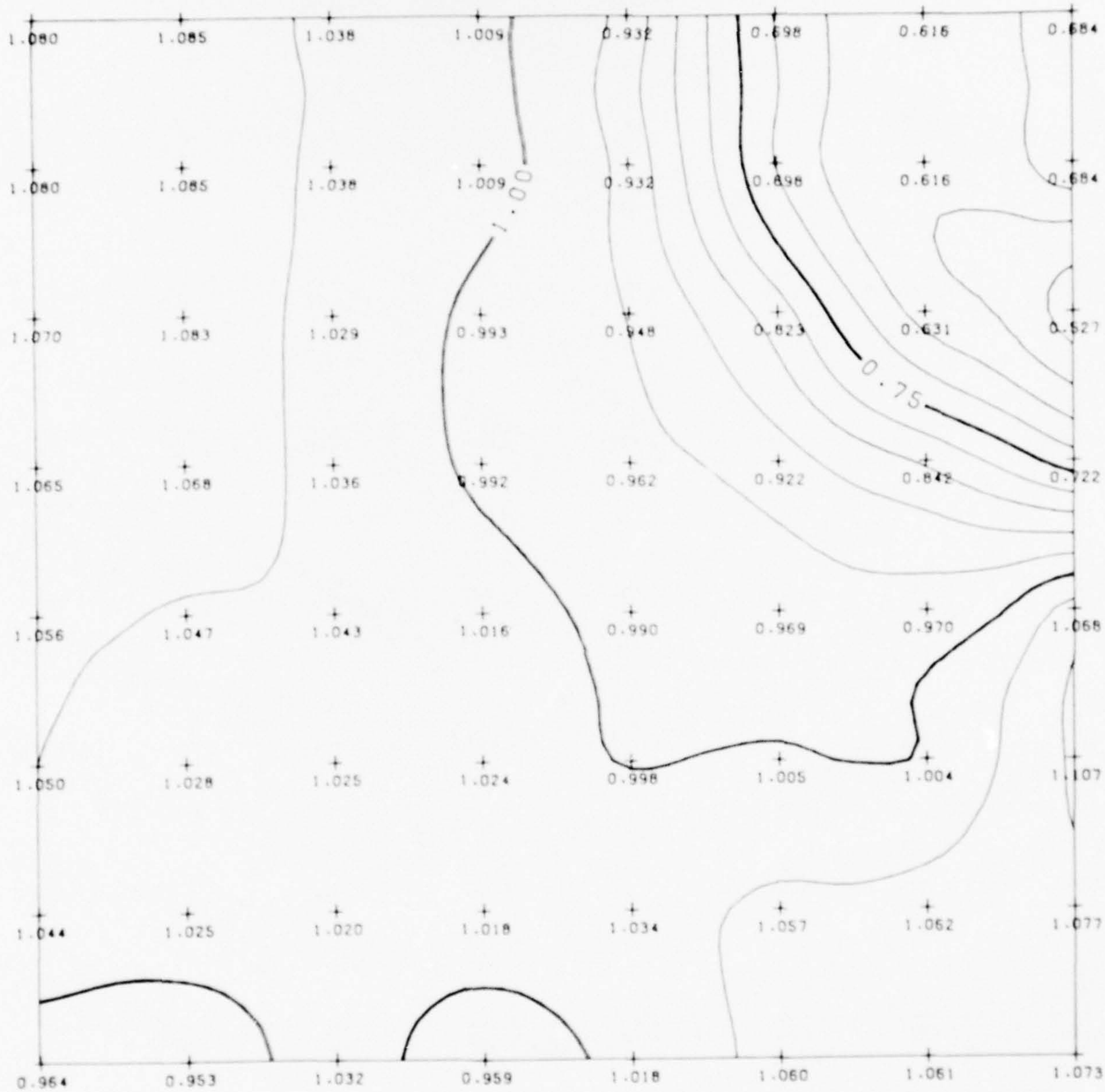
Haveg 41-N; 90° 3 Ft, Rocket Motor Mk 36
Block 1 of 4



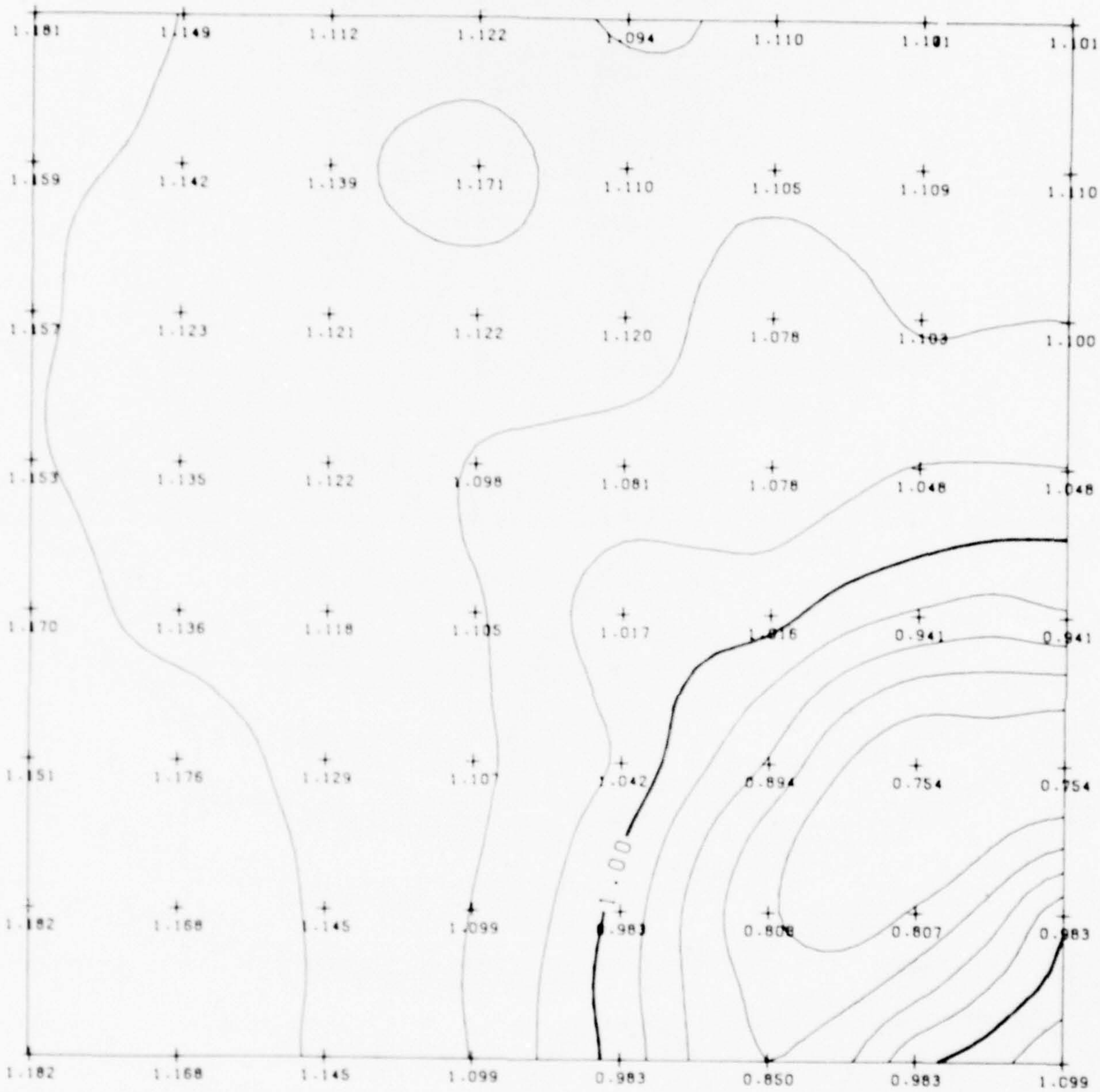
Kevlar; 90° 3 Ft, Rocket Motor Mk 36,
Block 2 of 4



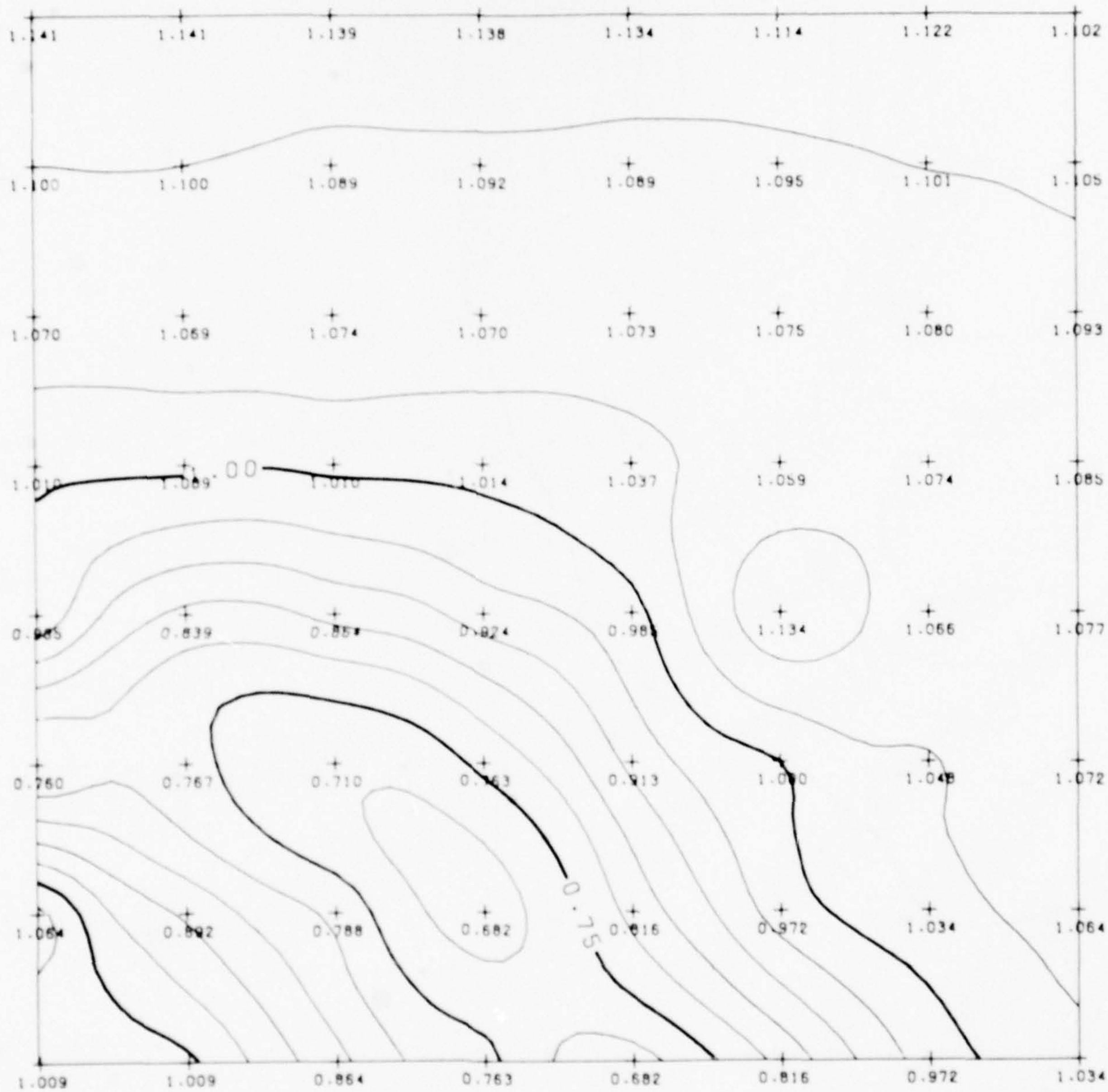
Dynatherm; 90° 3 Ft, Rocket Motor Mk 36,
Block 3 of 4



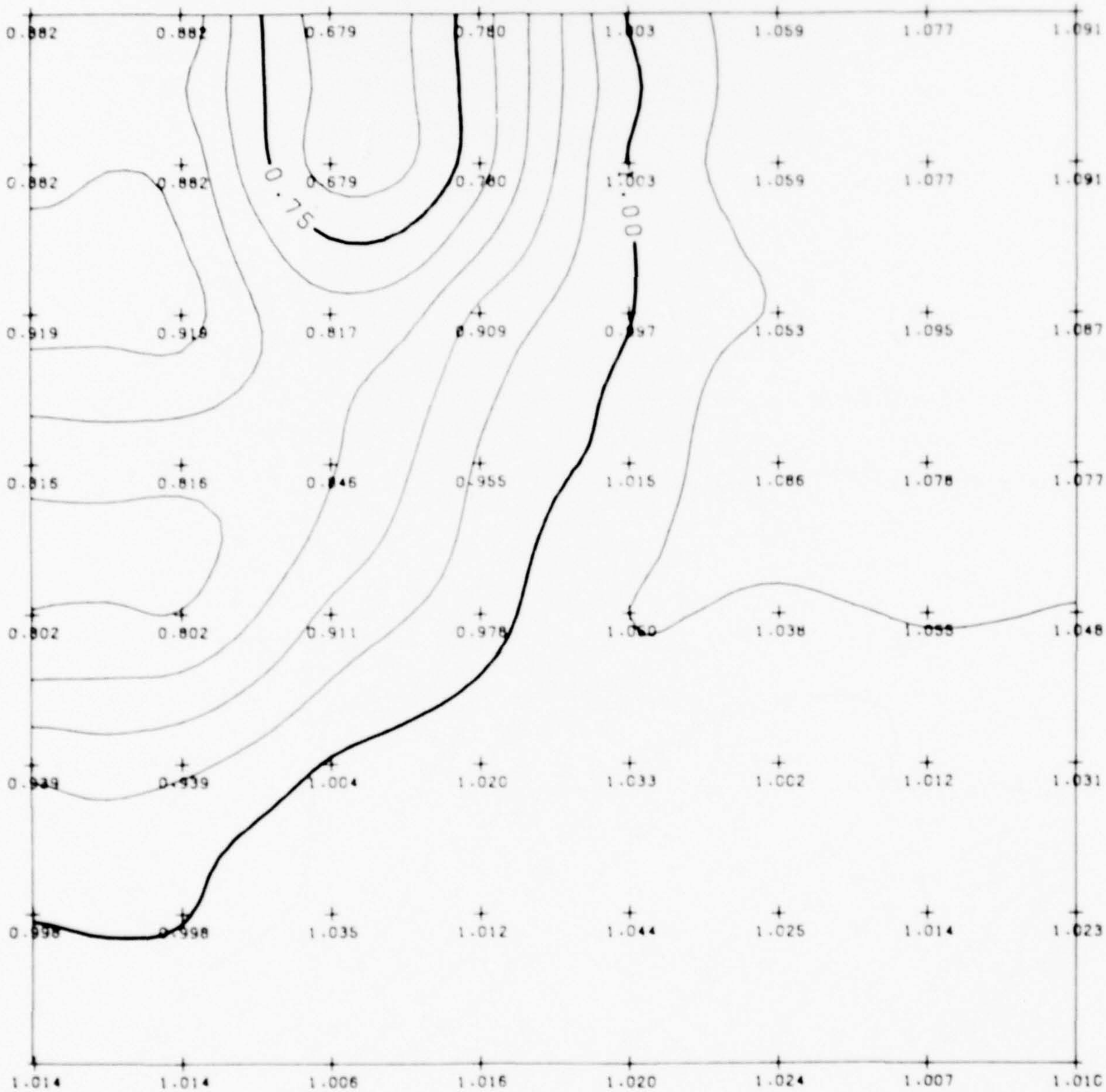
FMI; 90° 3 Ft, Rocket Motor Mk 36,
Block 4 of 4



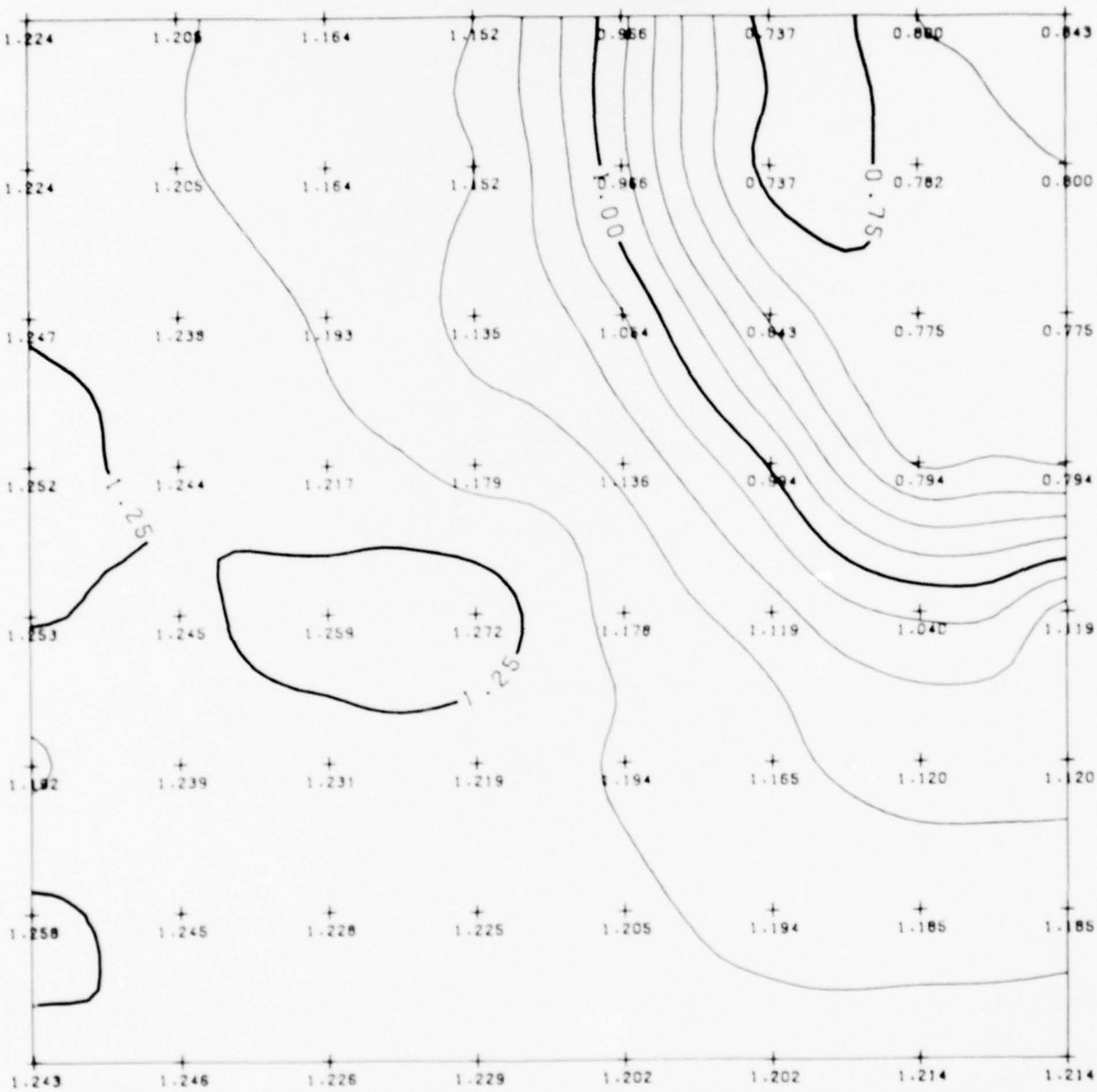
MXBE-350; 90° 3 Ft, Rocket Motor Mk 36,
Block 1 of 4



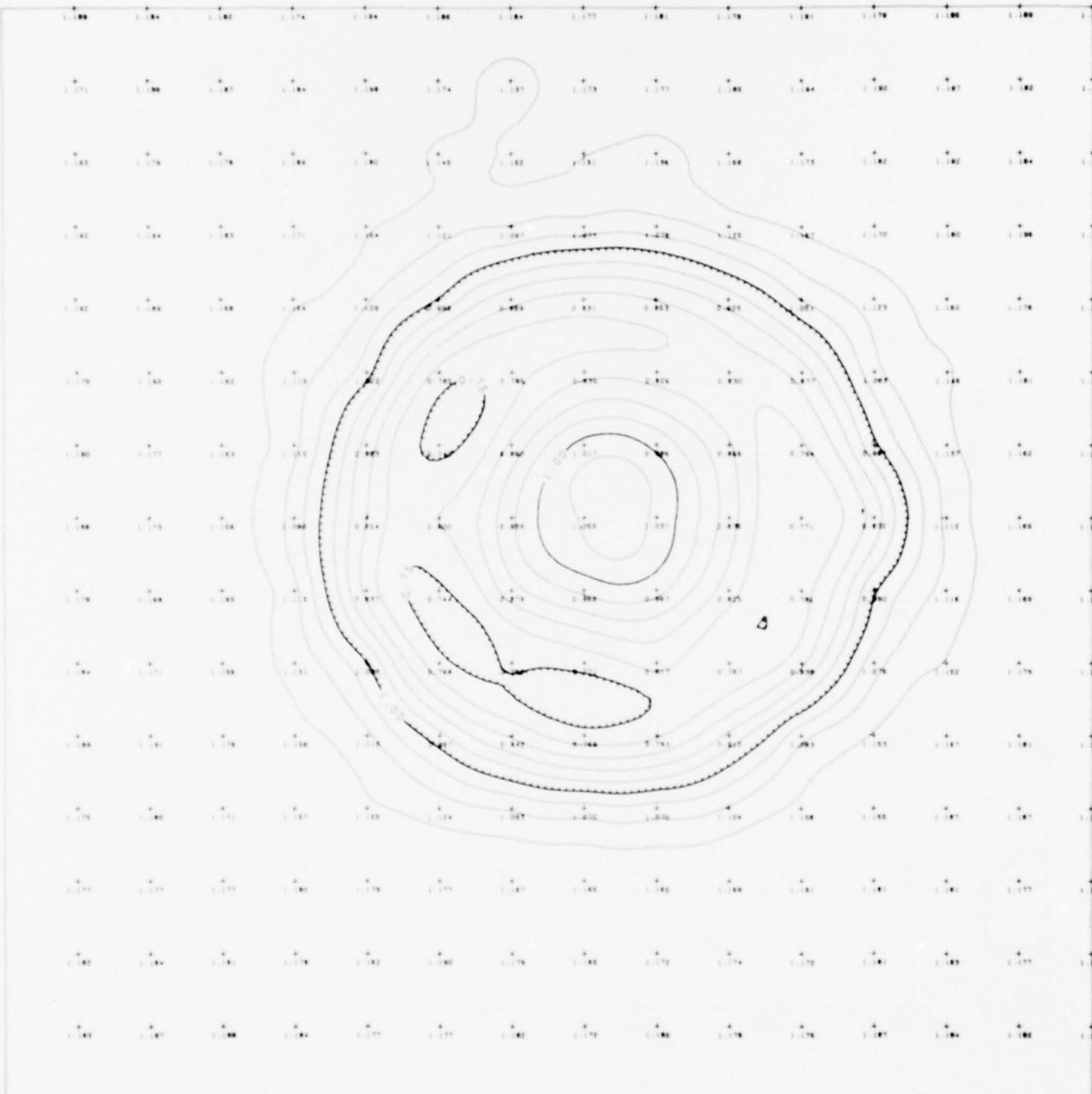
MBX-360; 90° 3 Ft, Rocket Motor Mk 36,
Block 2 of 4



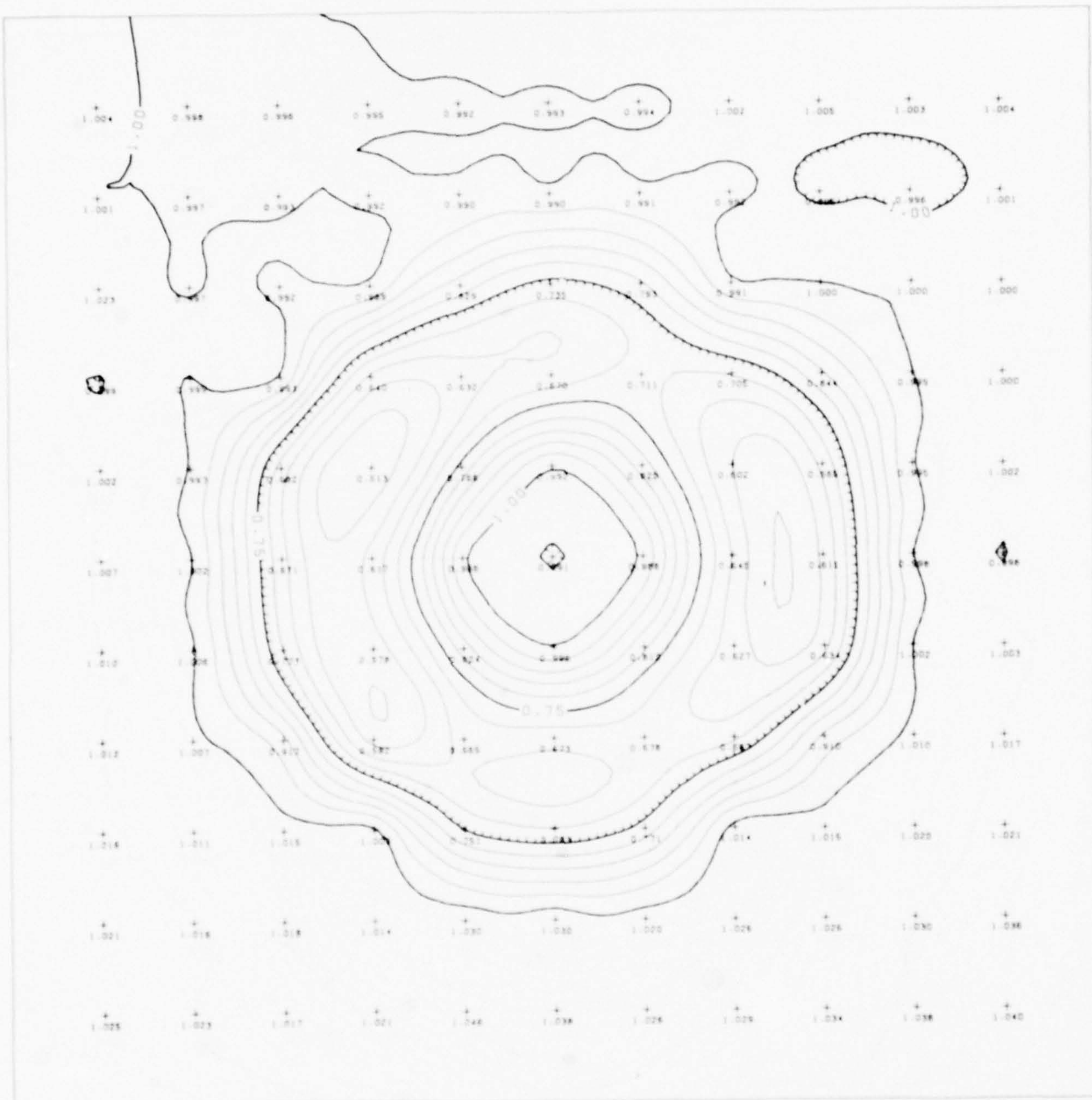
Dow Corning; 90° 3 Ft, Rocket Motor Mk 36,
Block 3 of 4



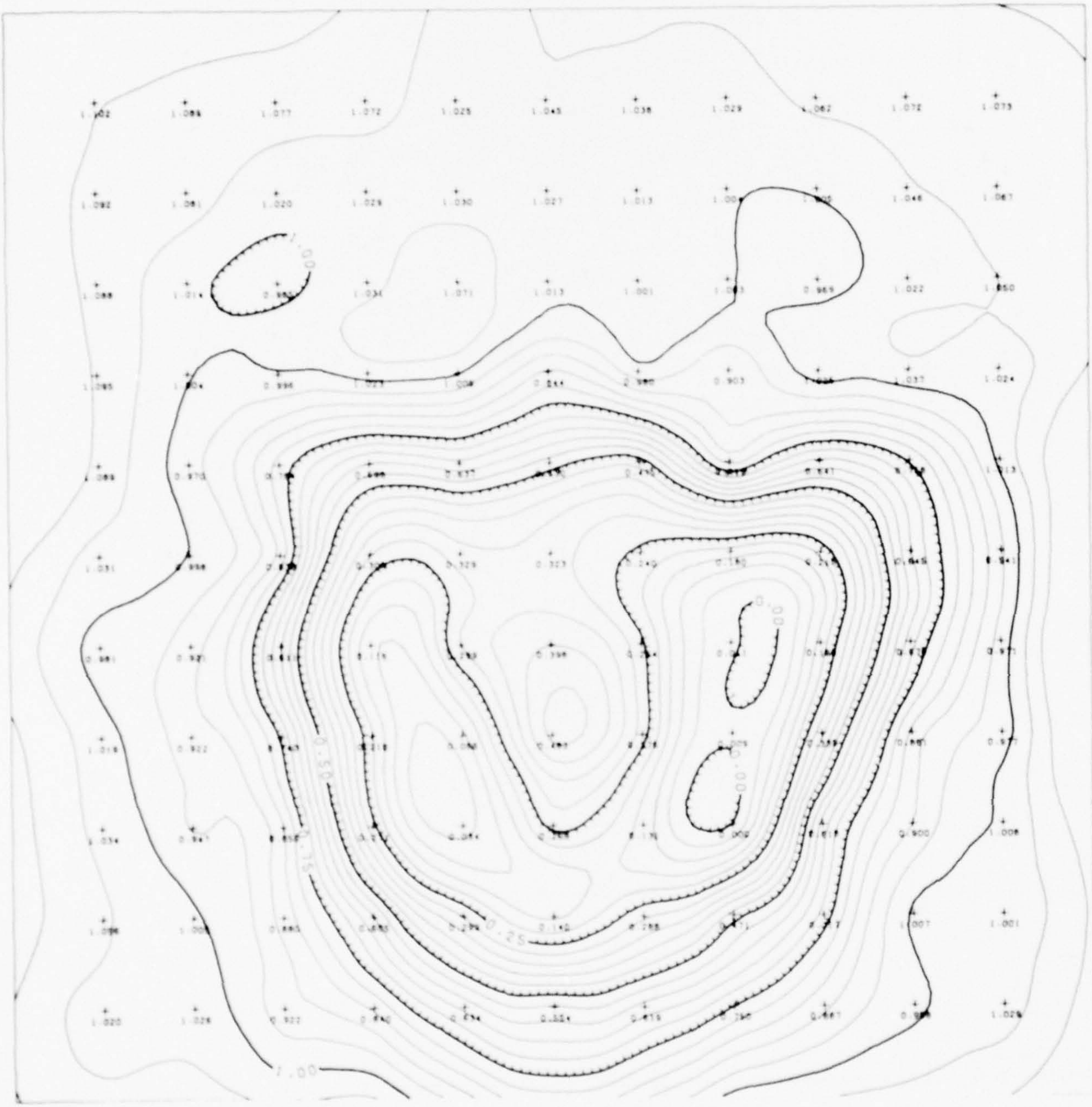
XB-1; 90° 3 Ft, Rocket Motor Mk 36, Block 4 of 4



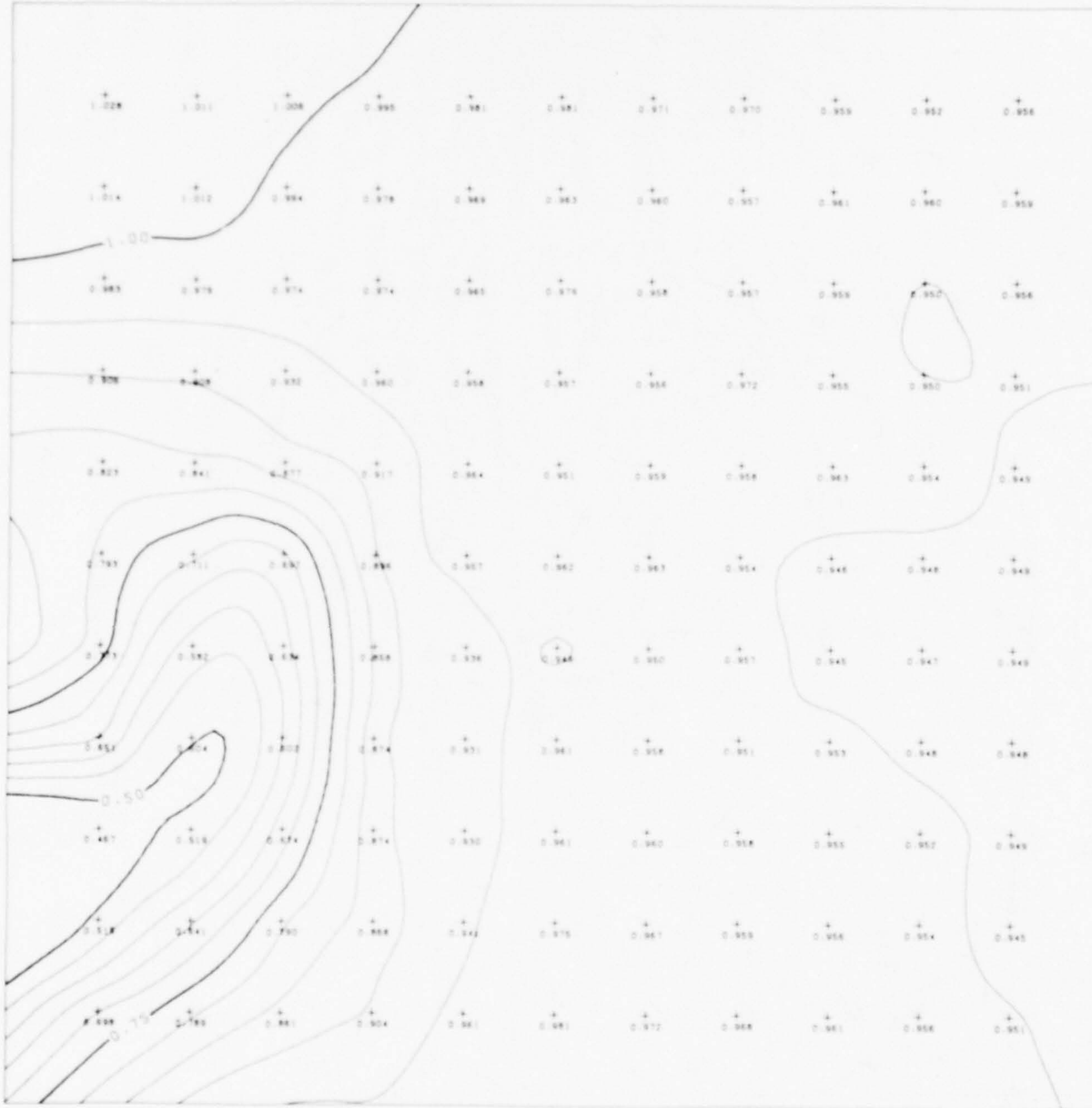
GER 1-B; 90° 3 Ft, Rocket Motor Mk 36



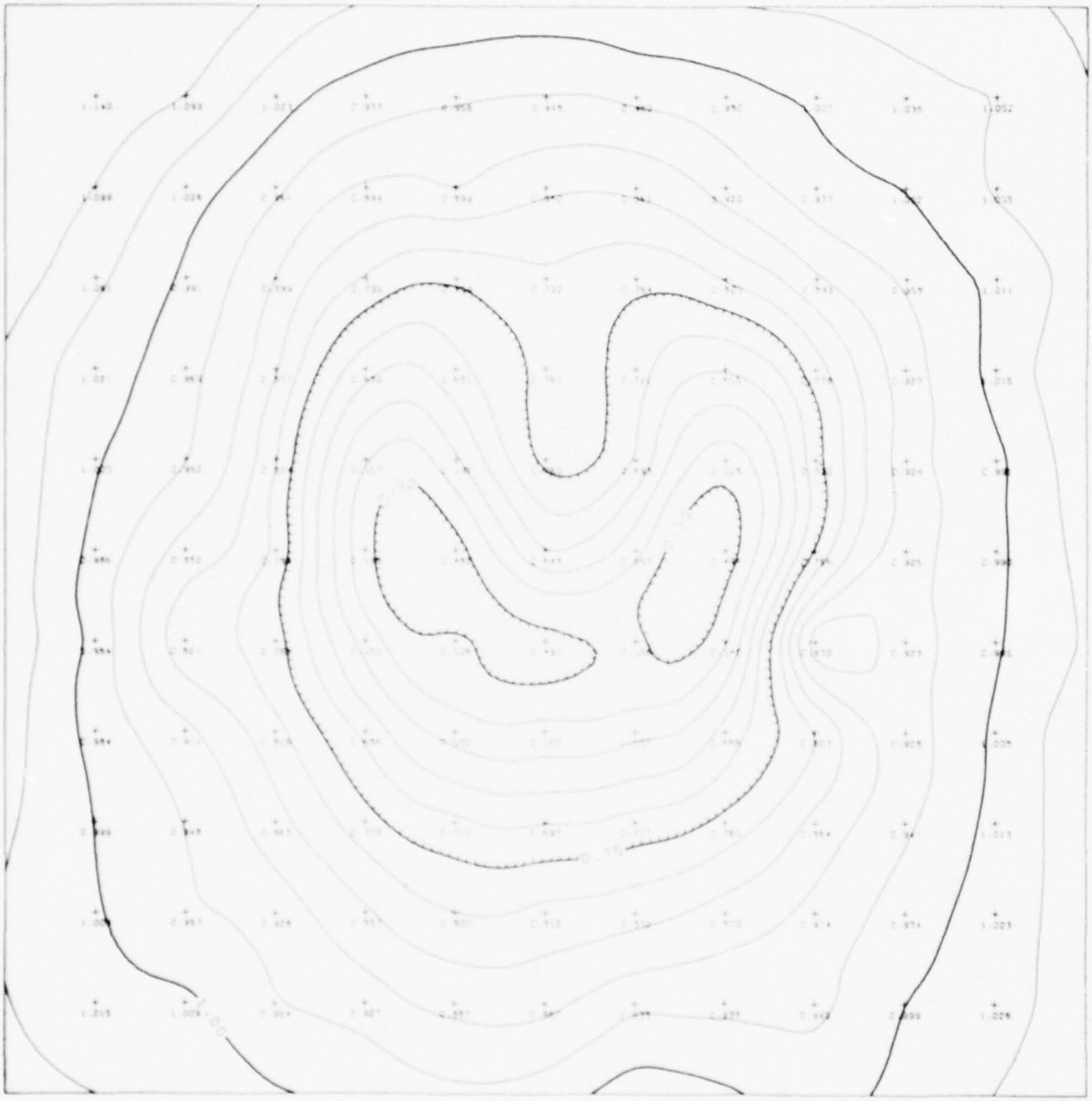
Steel; 90° 3 Ft, Rocket Motor Mk 36



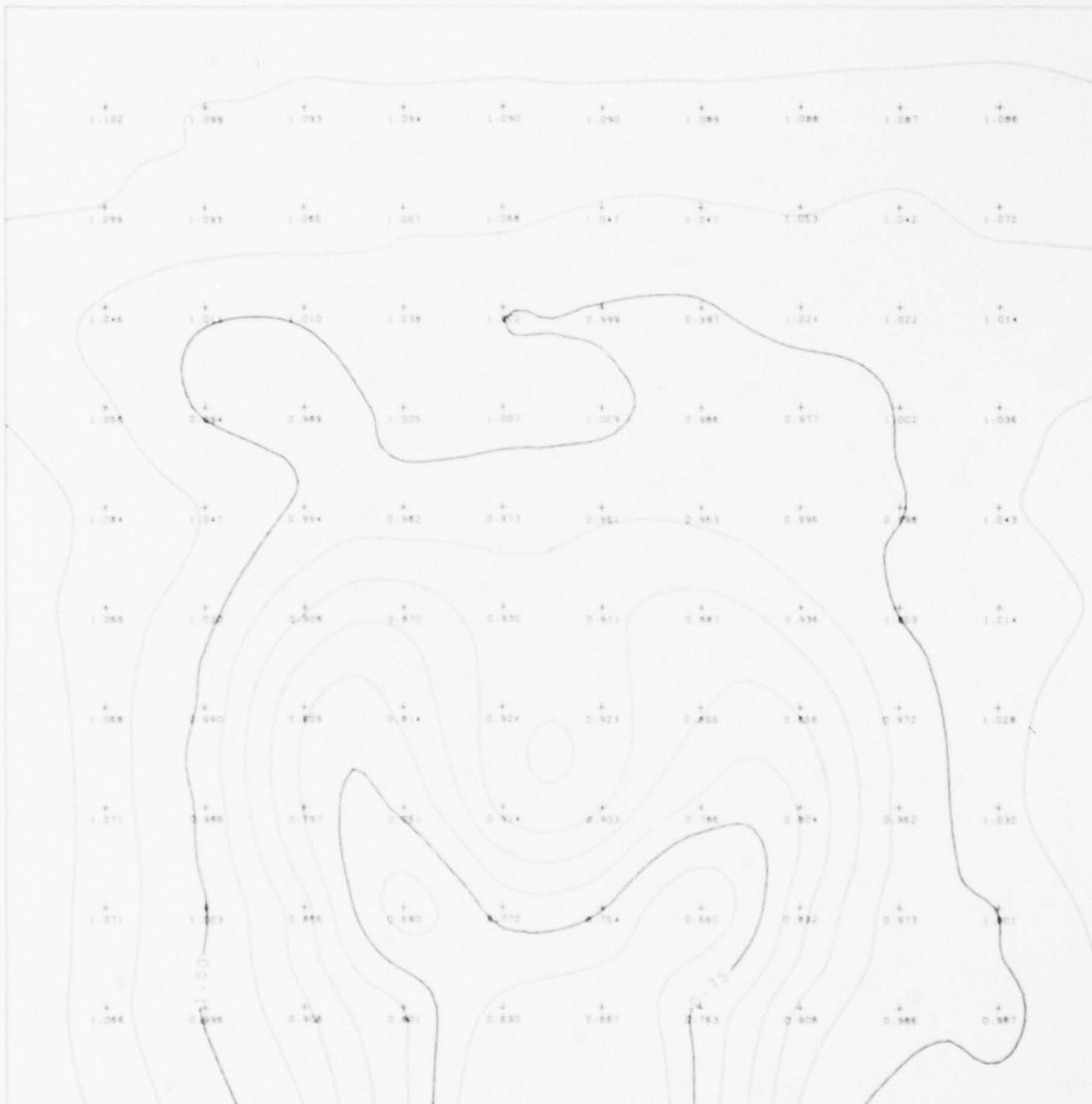
DC93-104; 32.5° 3 Ft, Rocket Motor Mk 36



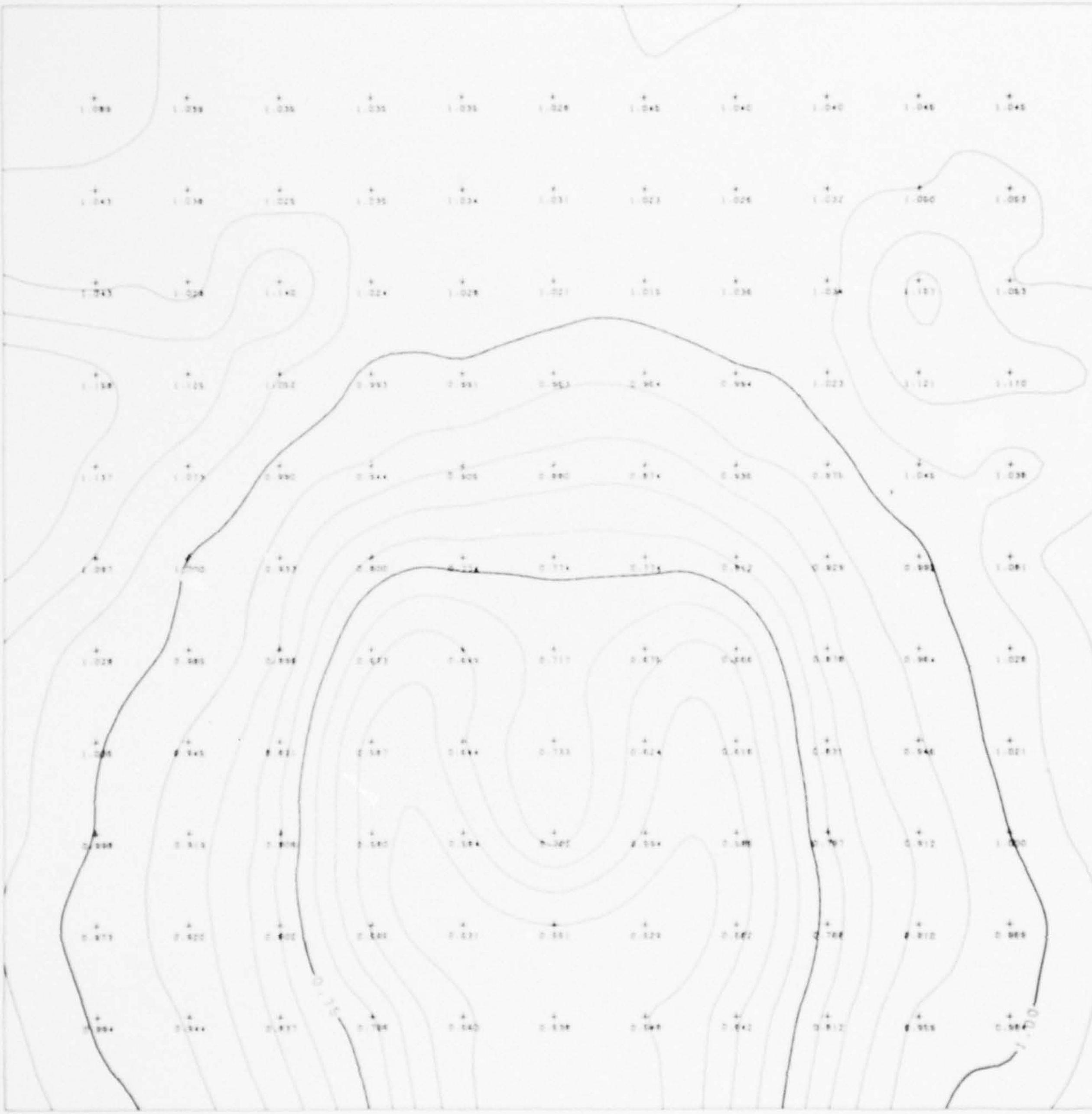
FR-1; 32.5° 3 Ft, Rocket Motor Mk 36, No. 2



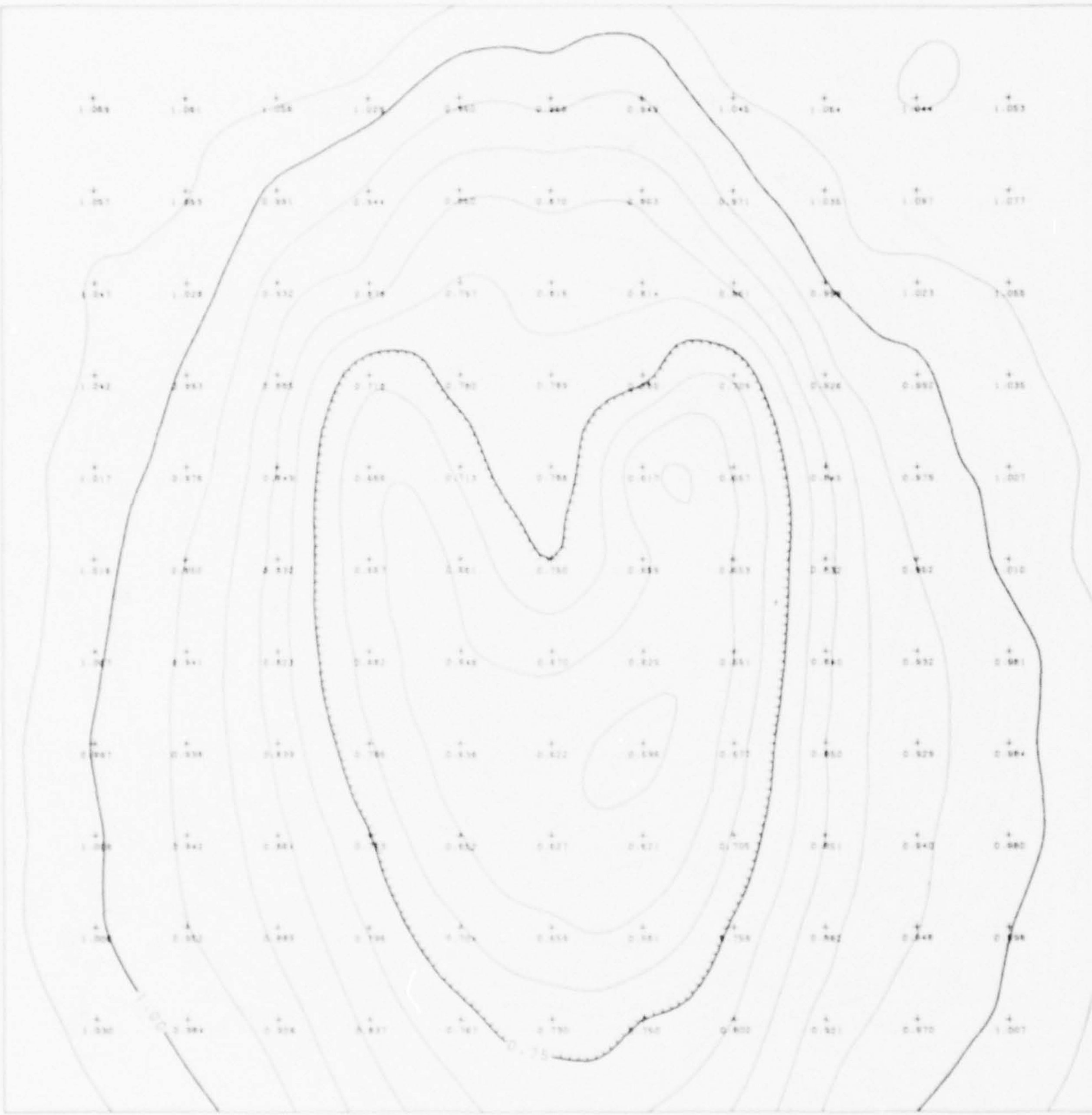
Haveg 41-N; 32.5° 3 Ft, Rocket Motor Mk 36



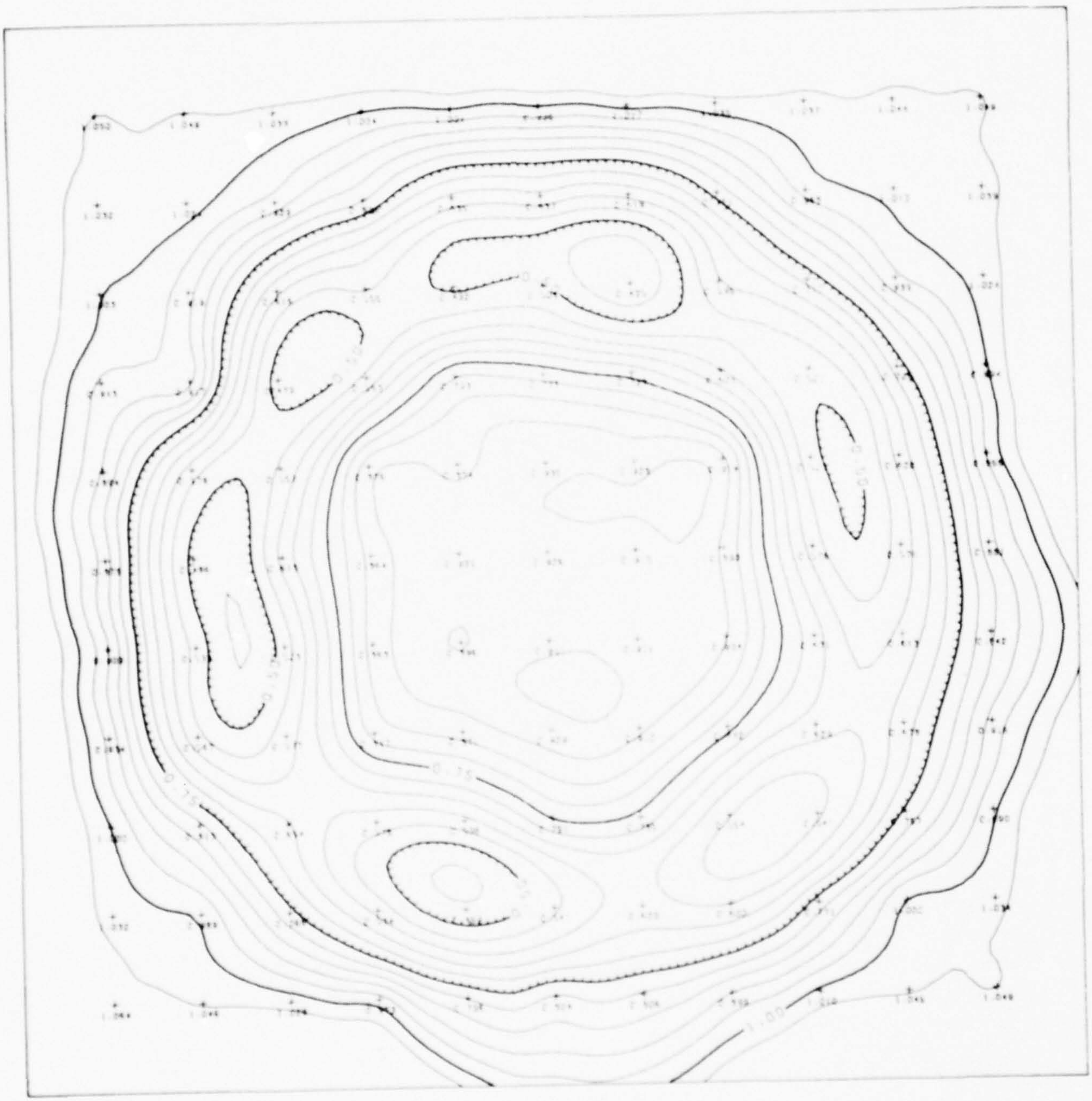
Hitco; 32.5° 3 Ft, Rocket Motor Mk 36



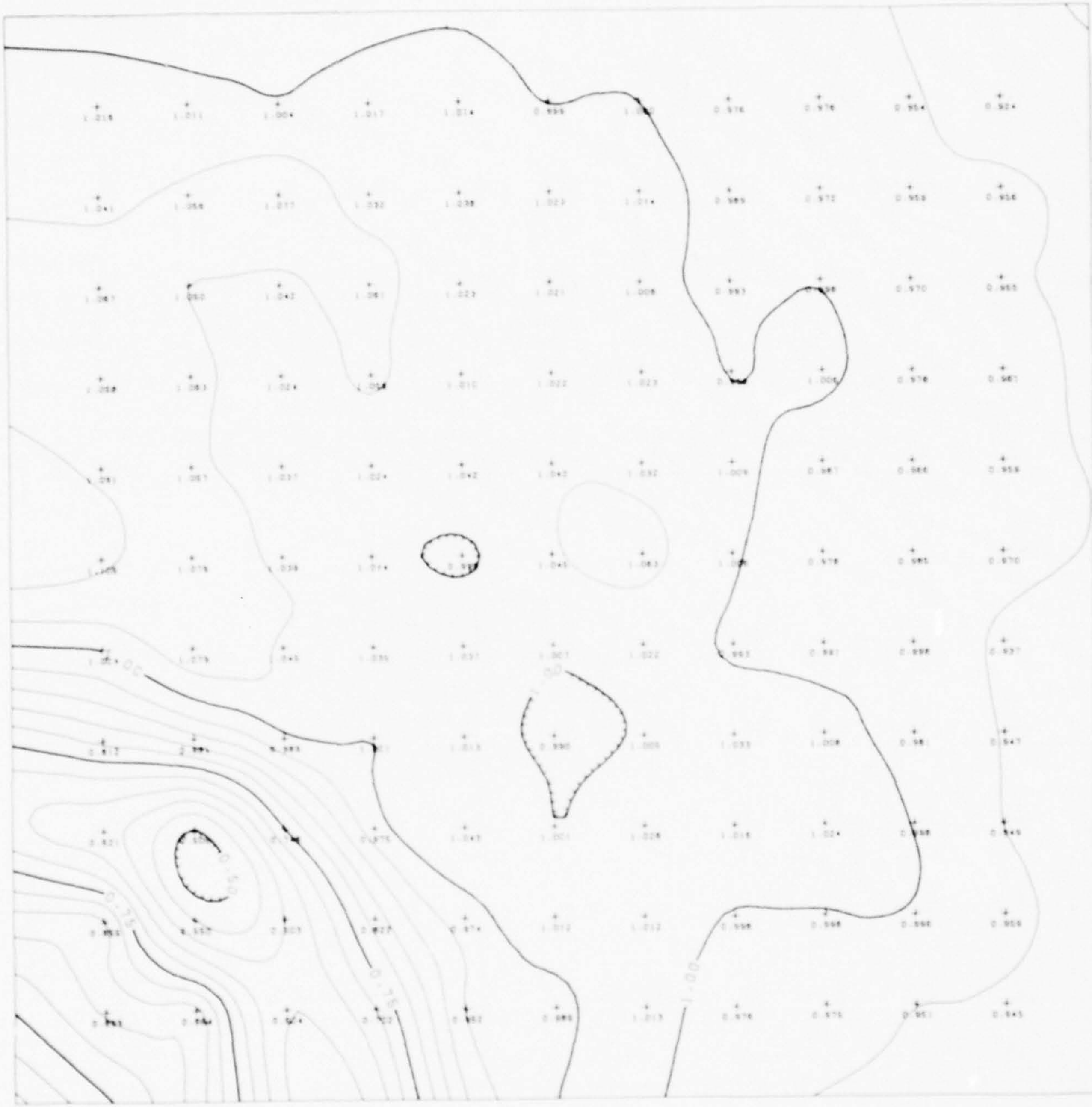
Haveg 41-N; 45° 3 Ft, Rocket Motor Mk 36



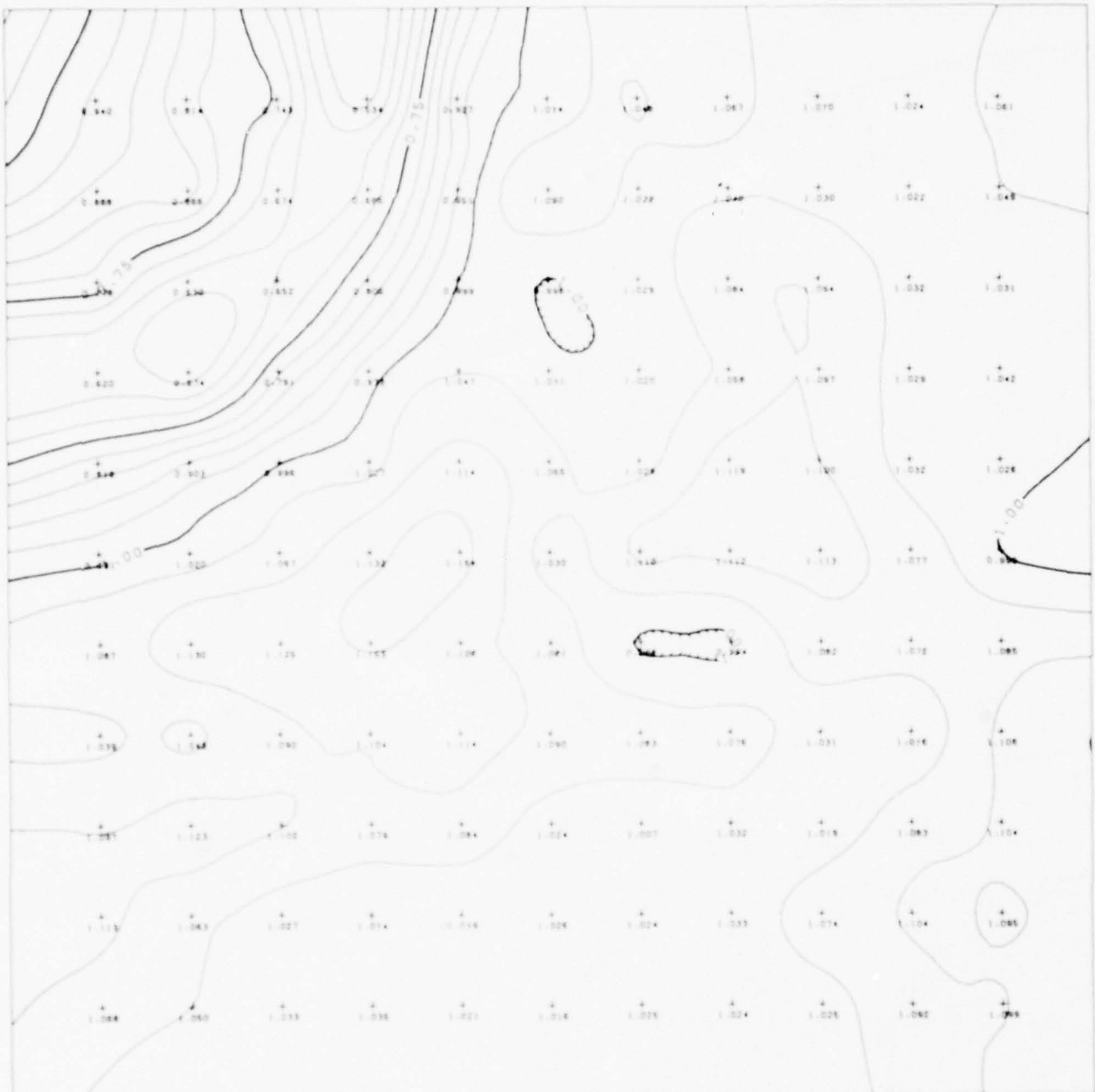
Haveg 41-N; 60° 3 Ft, Rocket Motor Mk 36



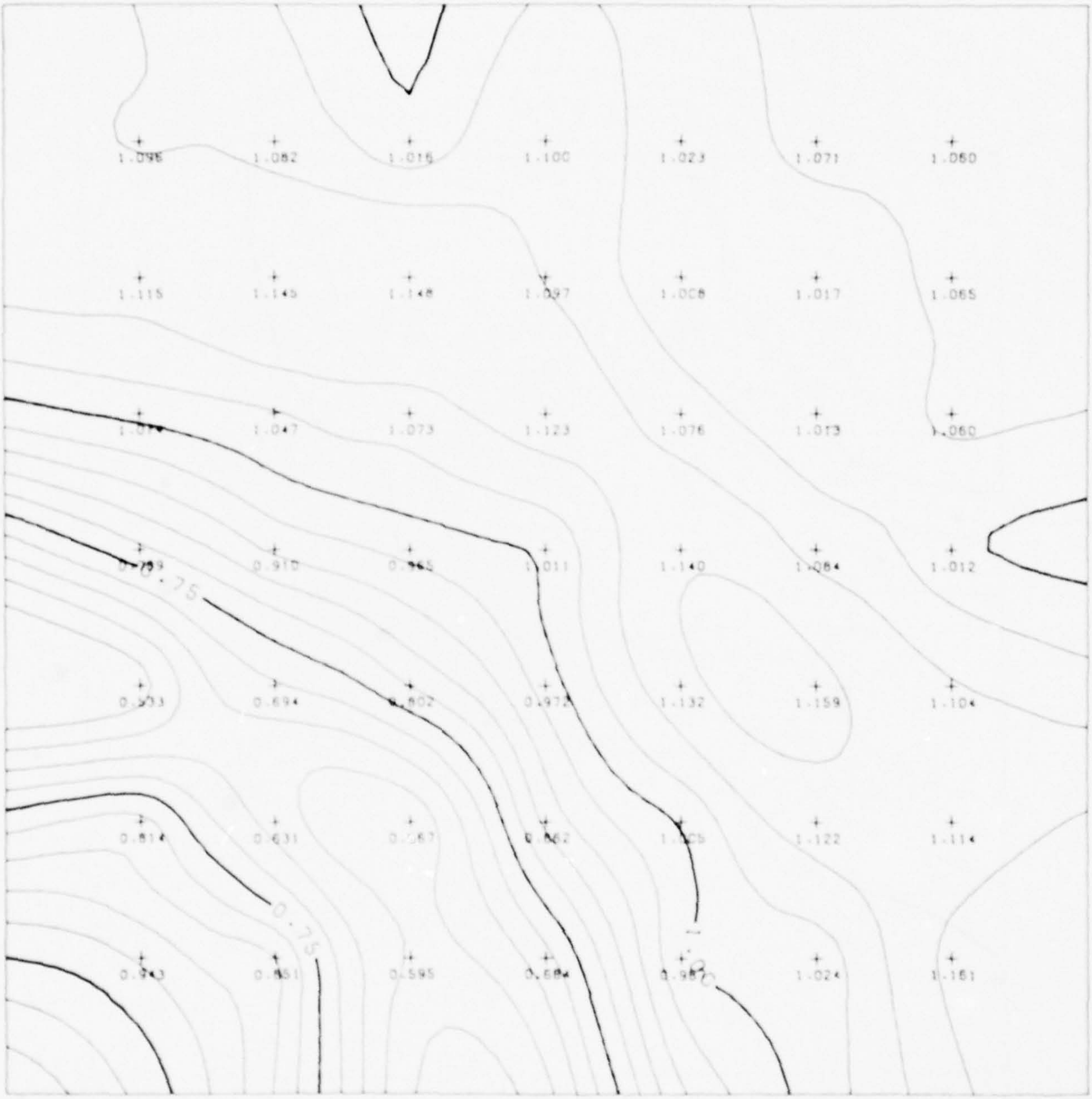
Haveg 41-N; 90° 1 Ft, Rocket Motor Mk 36



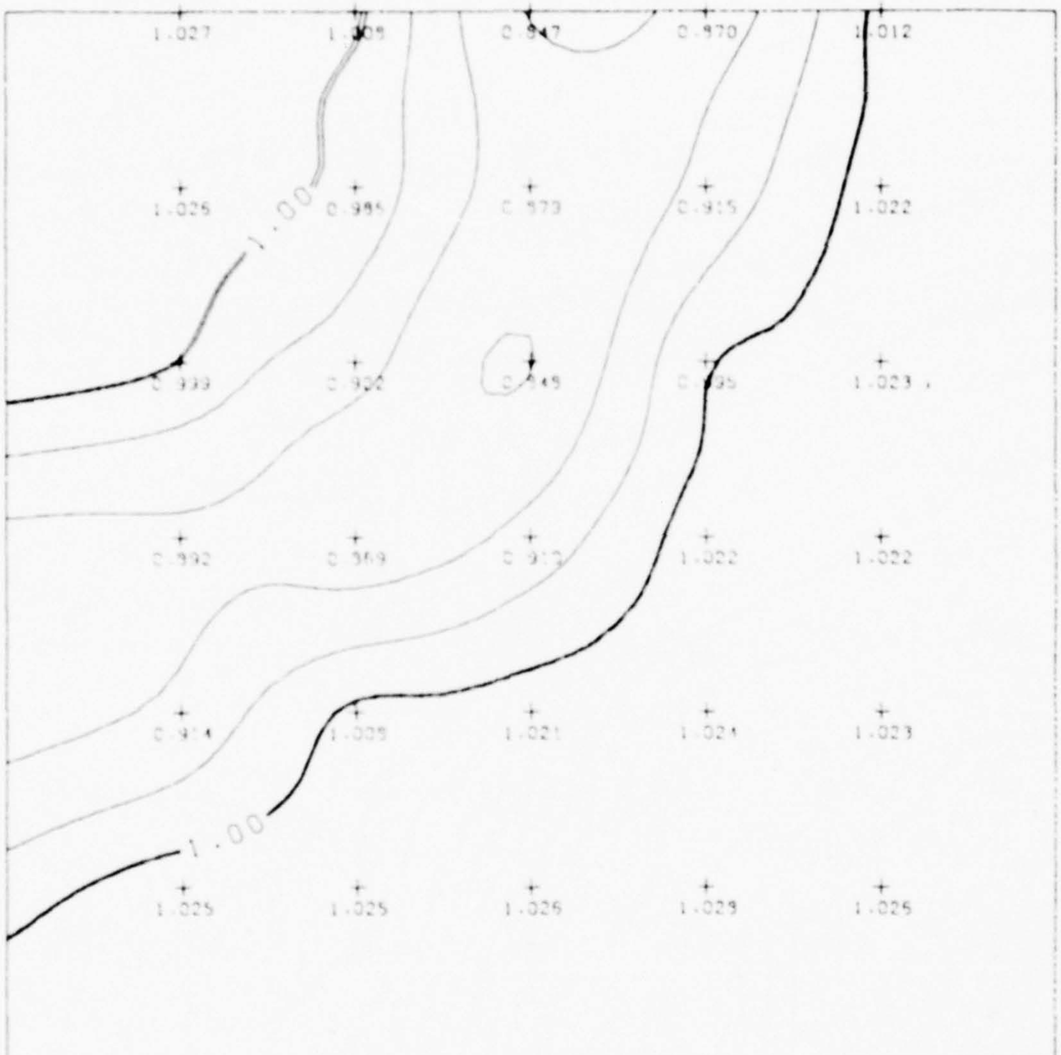
FR-1; 90° 1 Ft, Rocket Motor Mk 36, Block 2 of 4



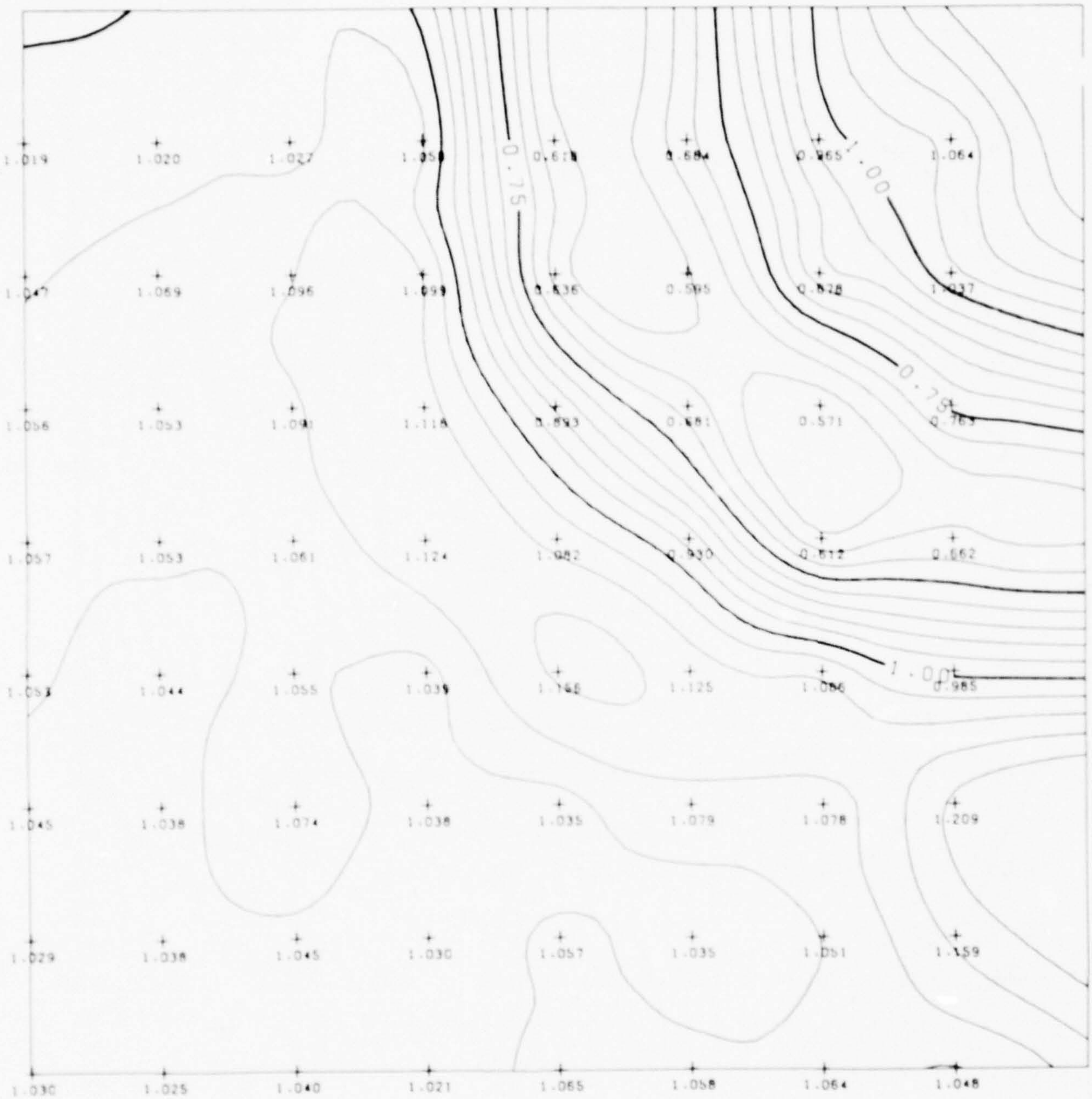
MXBE-350; 90° 1 Ft, Rocket Motor Mk 36, Block 3 of 4



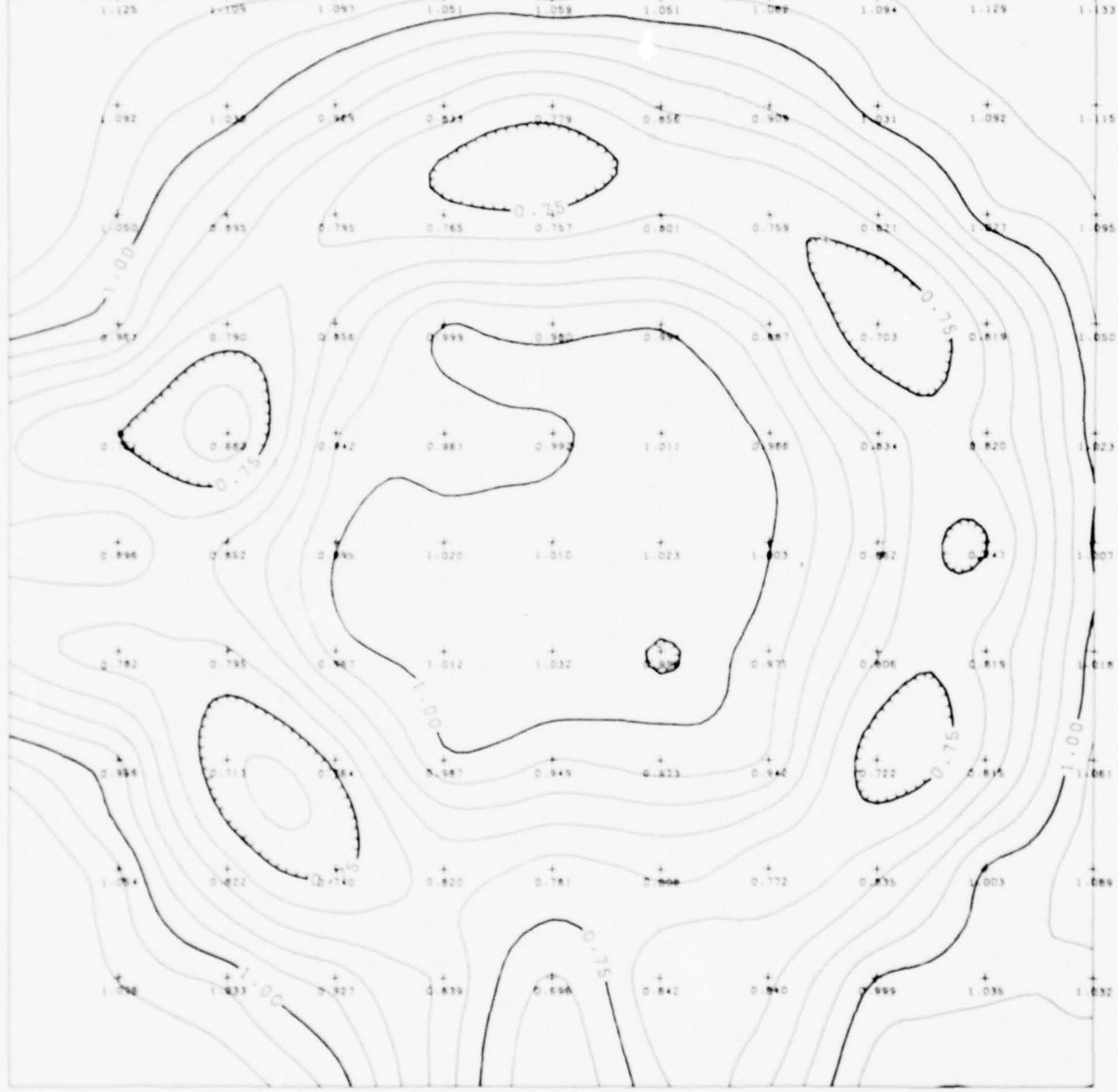
MXBE-350; 90° 1 Ft, Rocket Motor Mk 36, Block 2 of 4



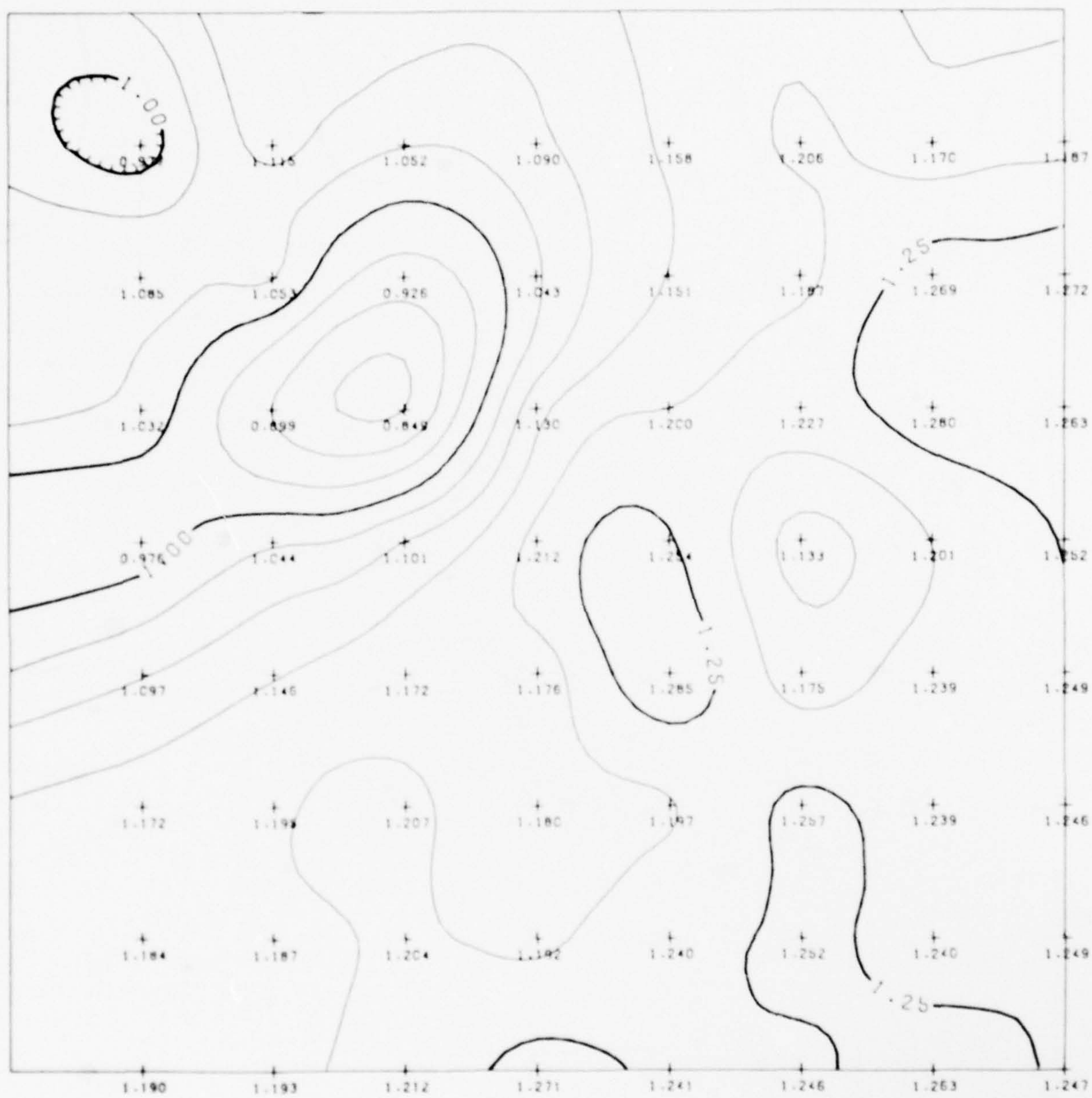
HDFG Carbon; 90° 1 Ft, Rocket Motor Mk 36, No. 3



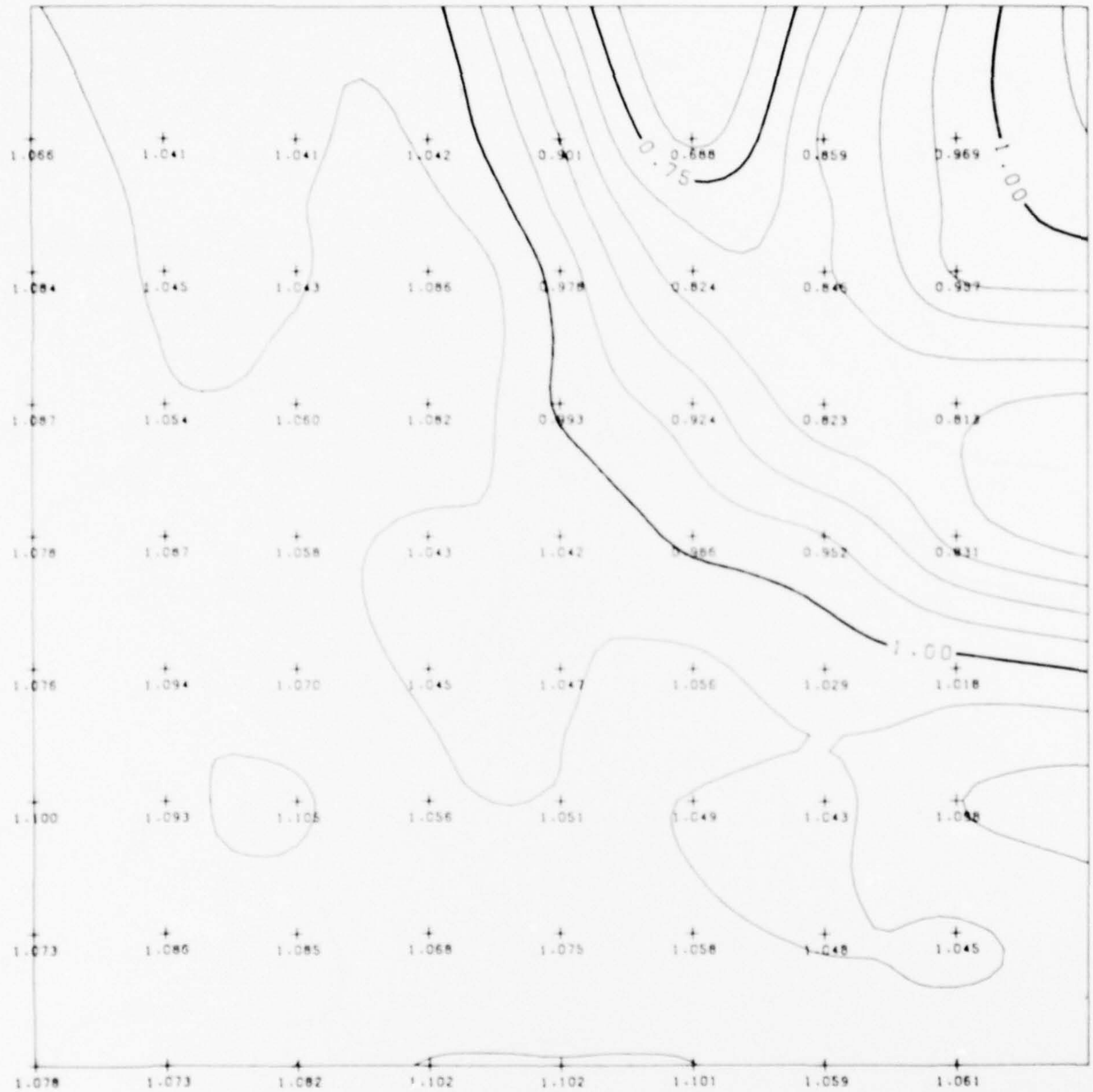
Steel; 90° 1 Ft, Rocket Motor Mk 36, Block 4 of 4



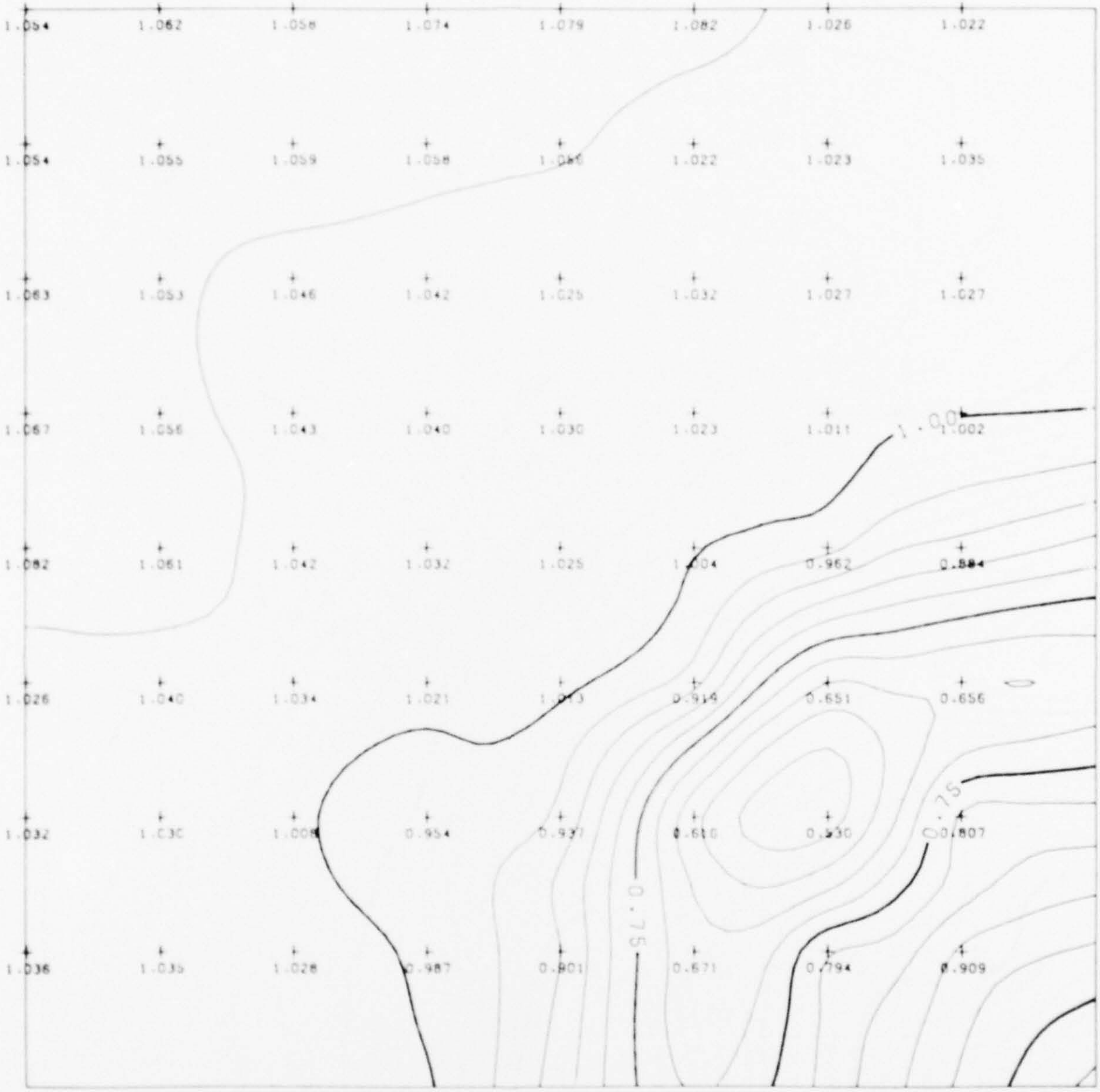
Hitco; 90° 1 Ft, Rocket Motor Mk 36



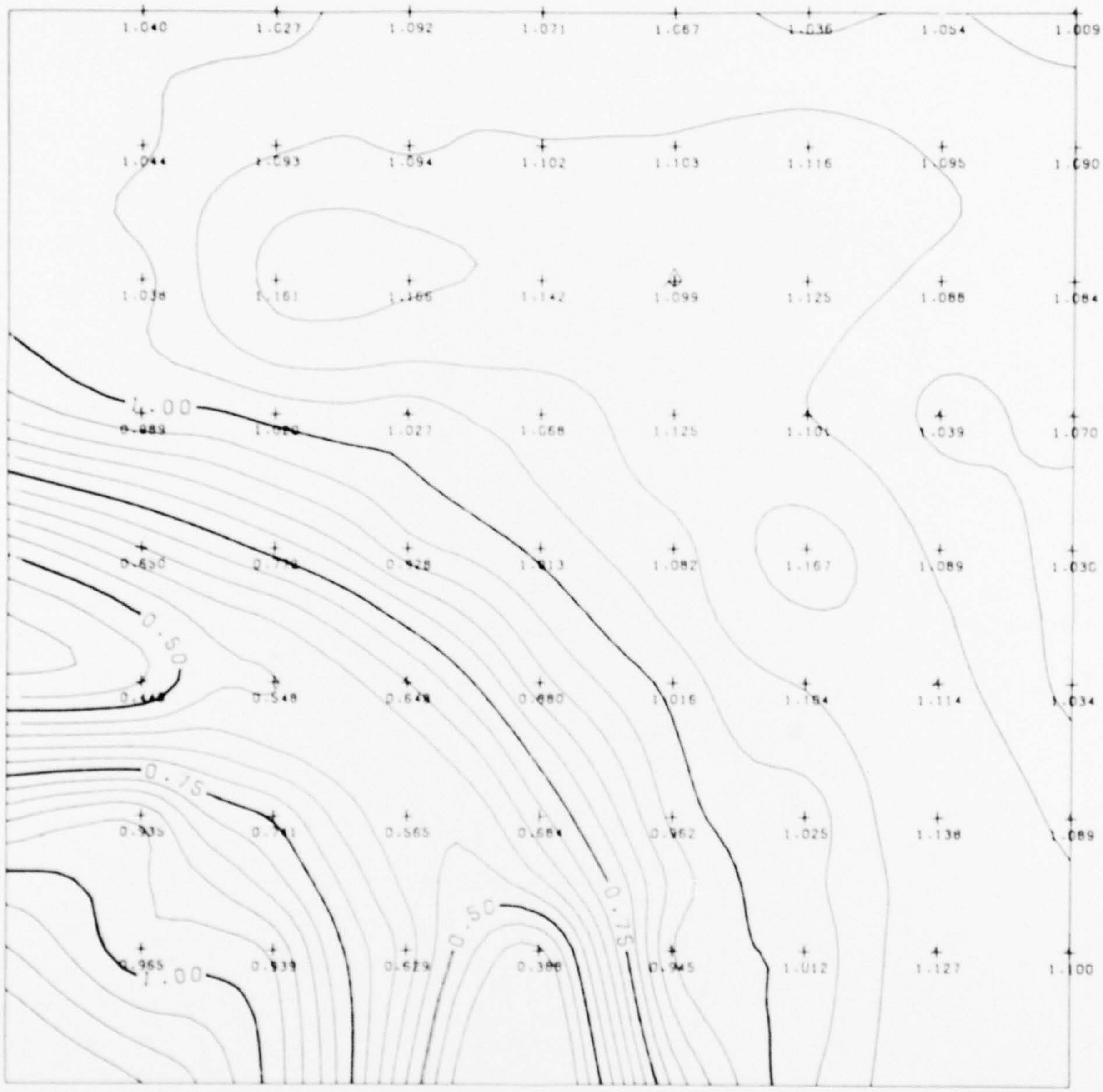
FR-2; 90° 1 Ft, Rocket Motor Mk 36, Block 3 of 4



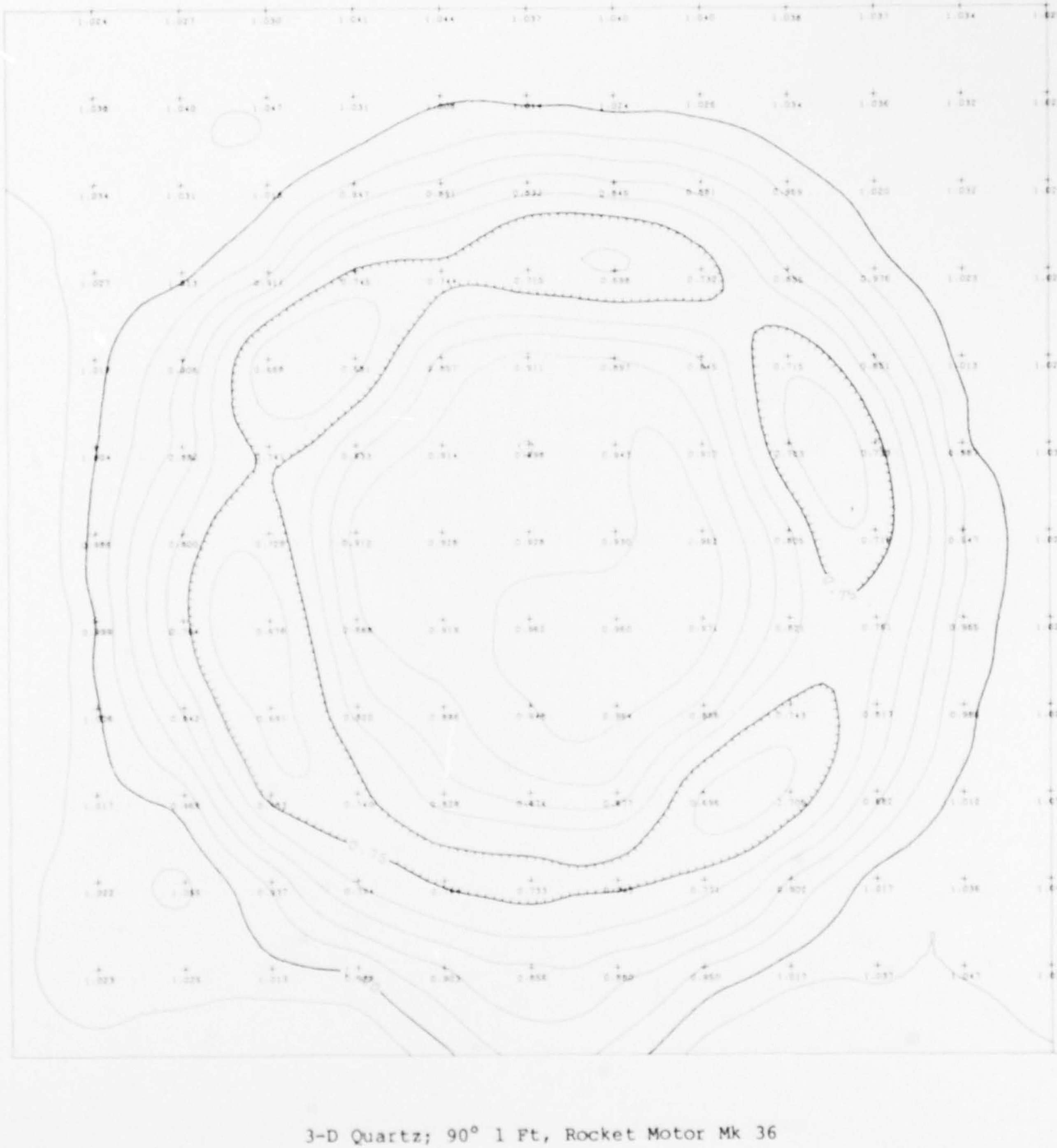
FR-2; 90° 1 Ft, Rocket Motor Mk 36, Block 4 of 4



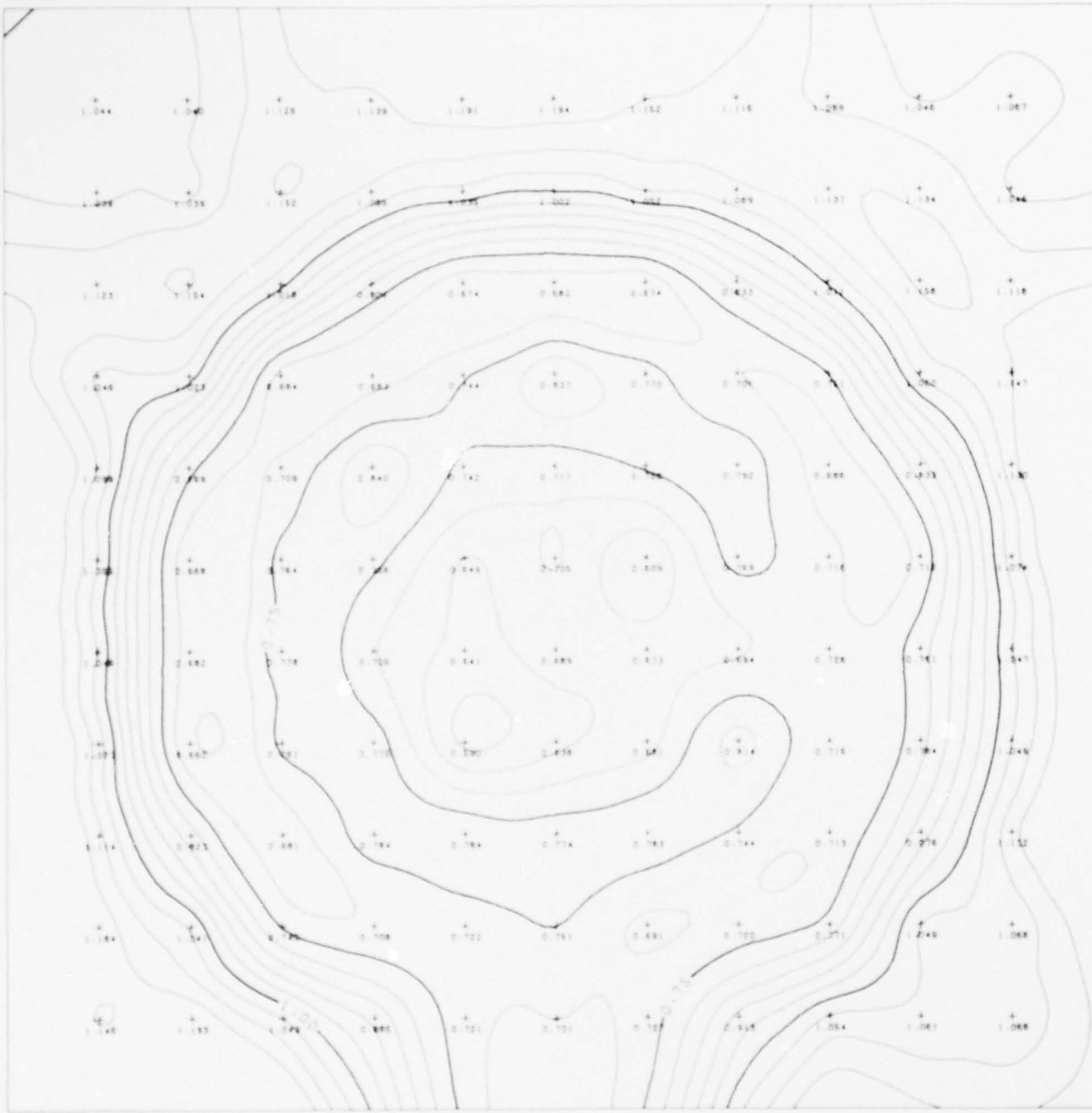
FR-3; 90° 1 Ft, Rocket Motor Mk 36, Block 1 of 4



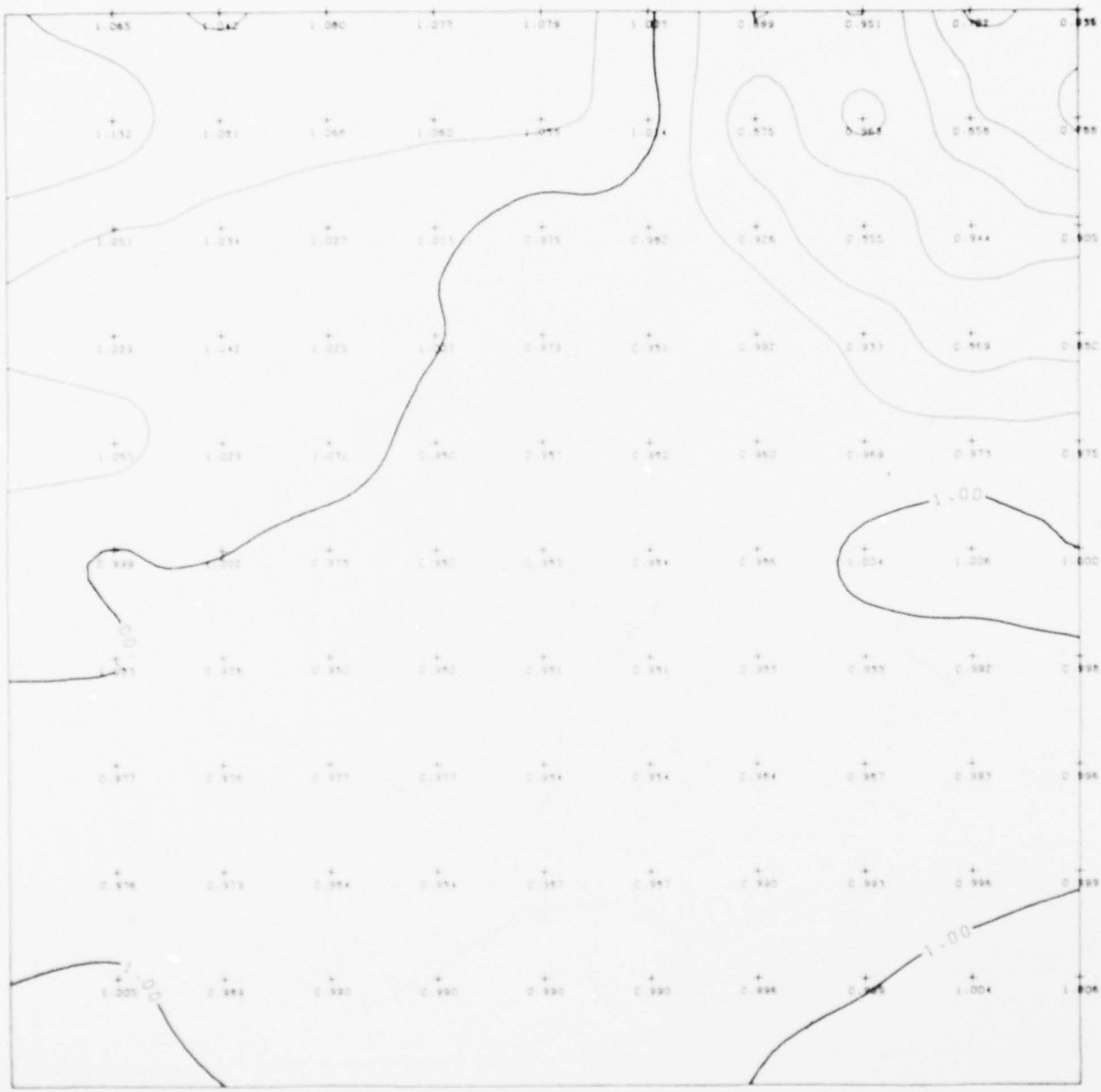
Haveg 41-N; 90° 1 Ft, Rocket Motor Mk 36, Block 2 of 4



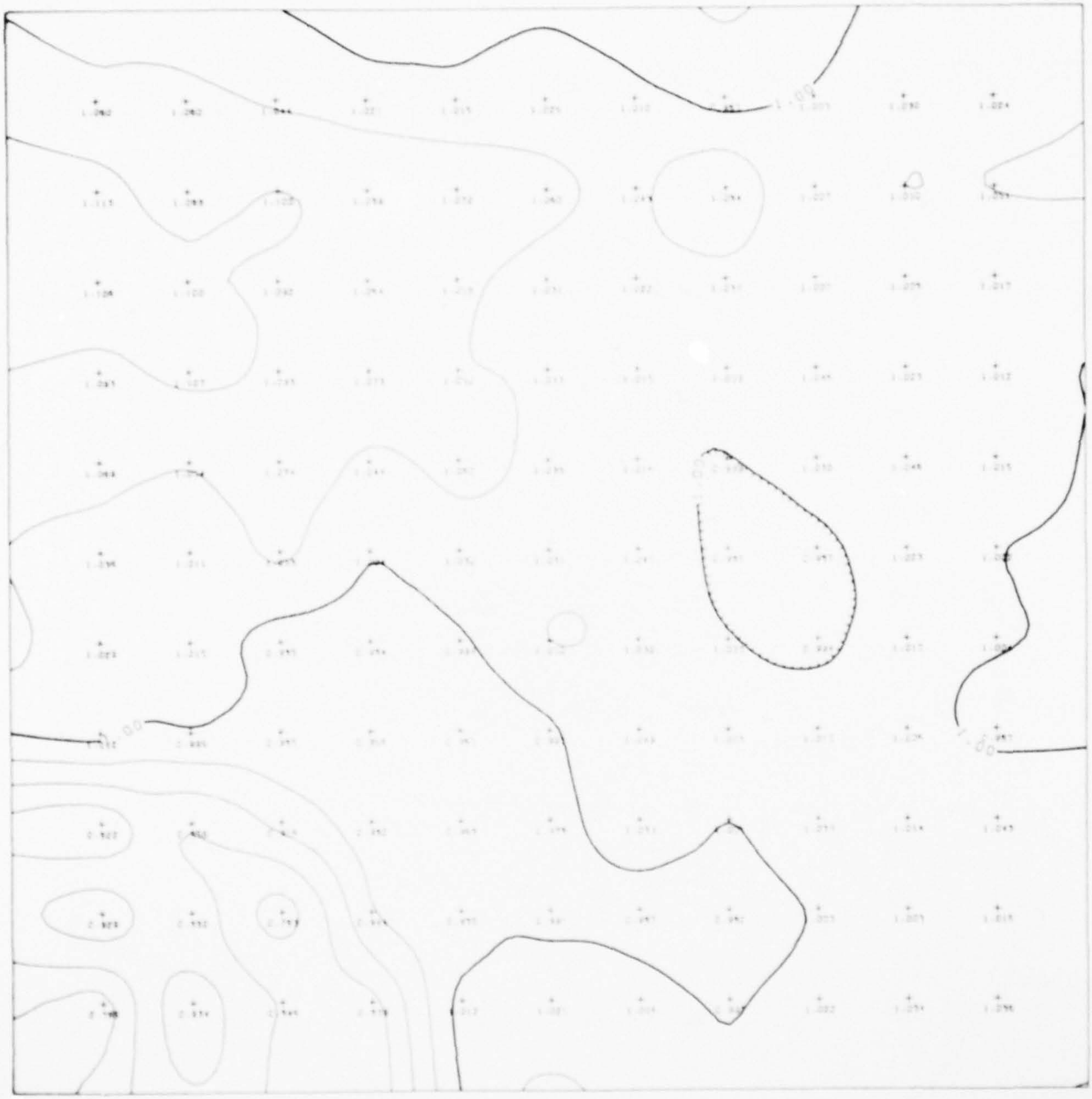
3-D Quartz; 90° 1 Ft, Rocket Motor Mk 36



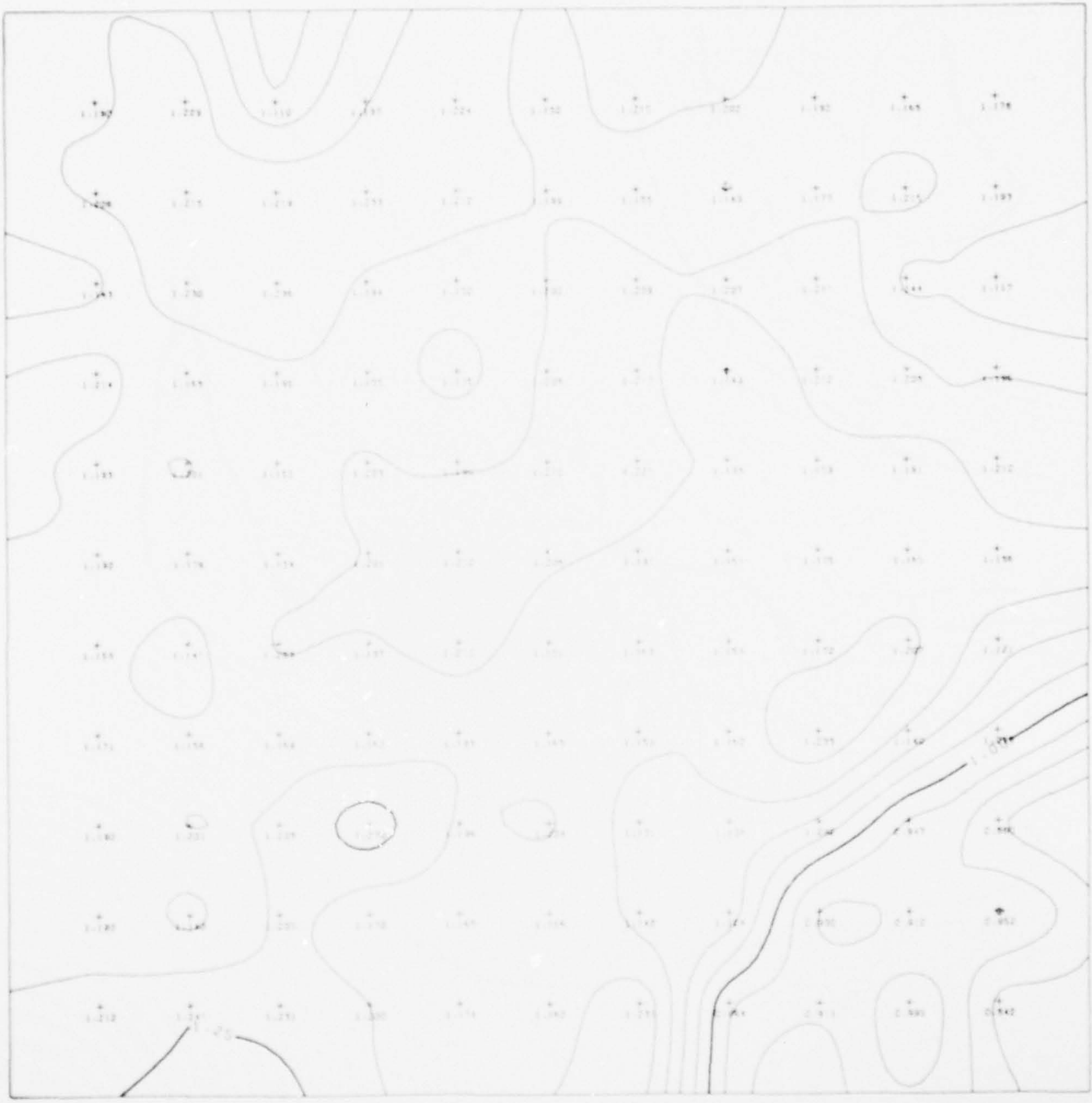
Haveg 41-N; 90° 0.5 Ft, Rocket Motor Mk 36



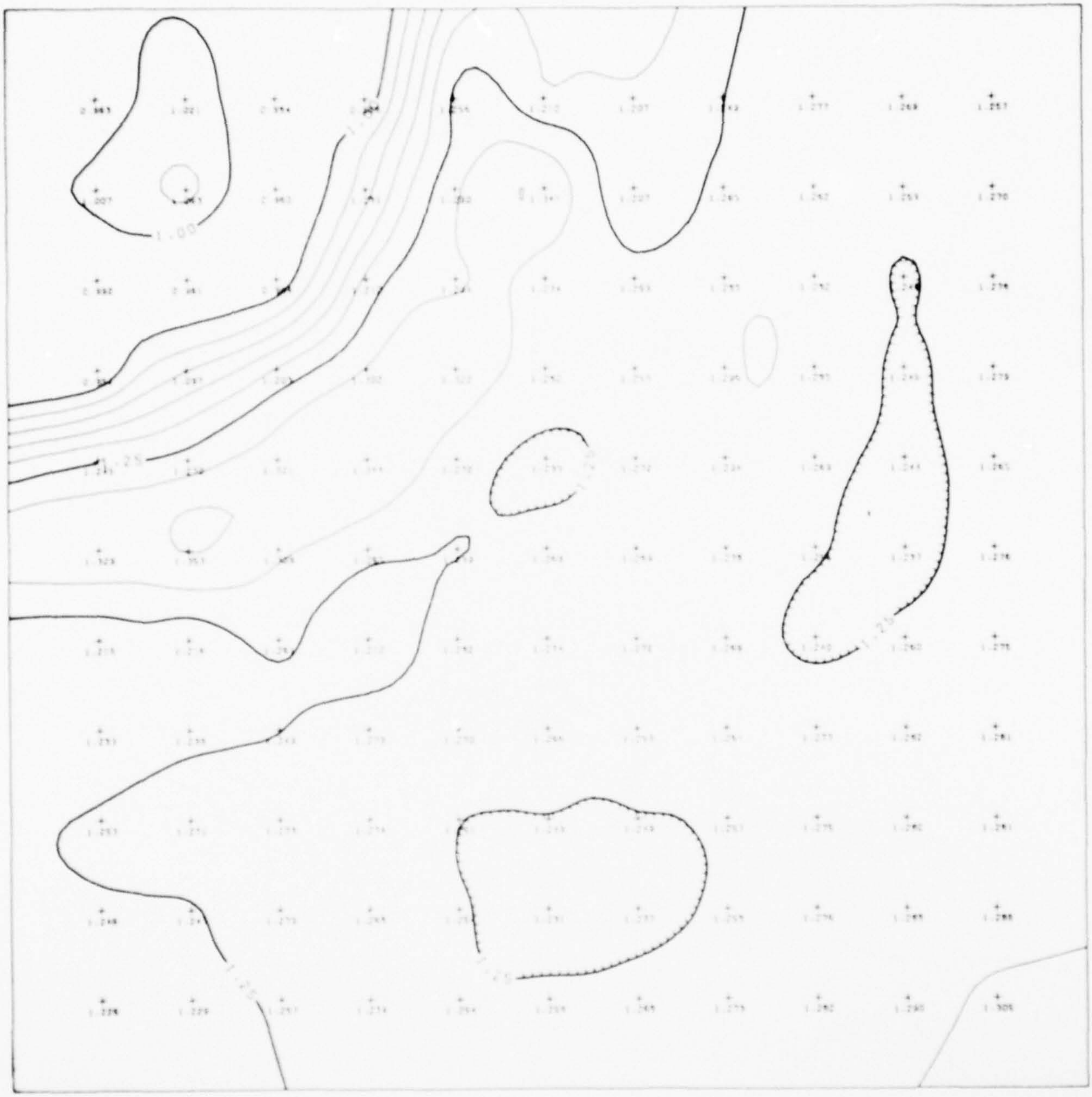
Hitco; 90° 0.5 Ft, Rocket Motor Mk 36



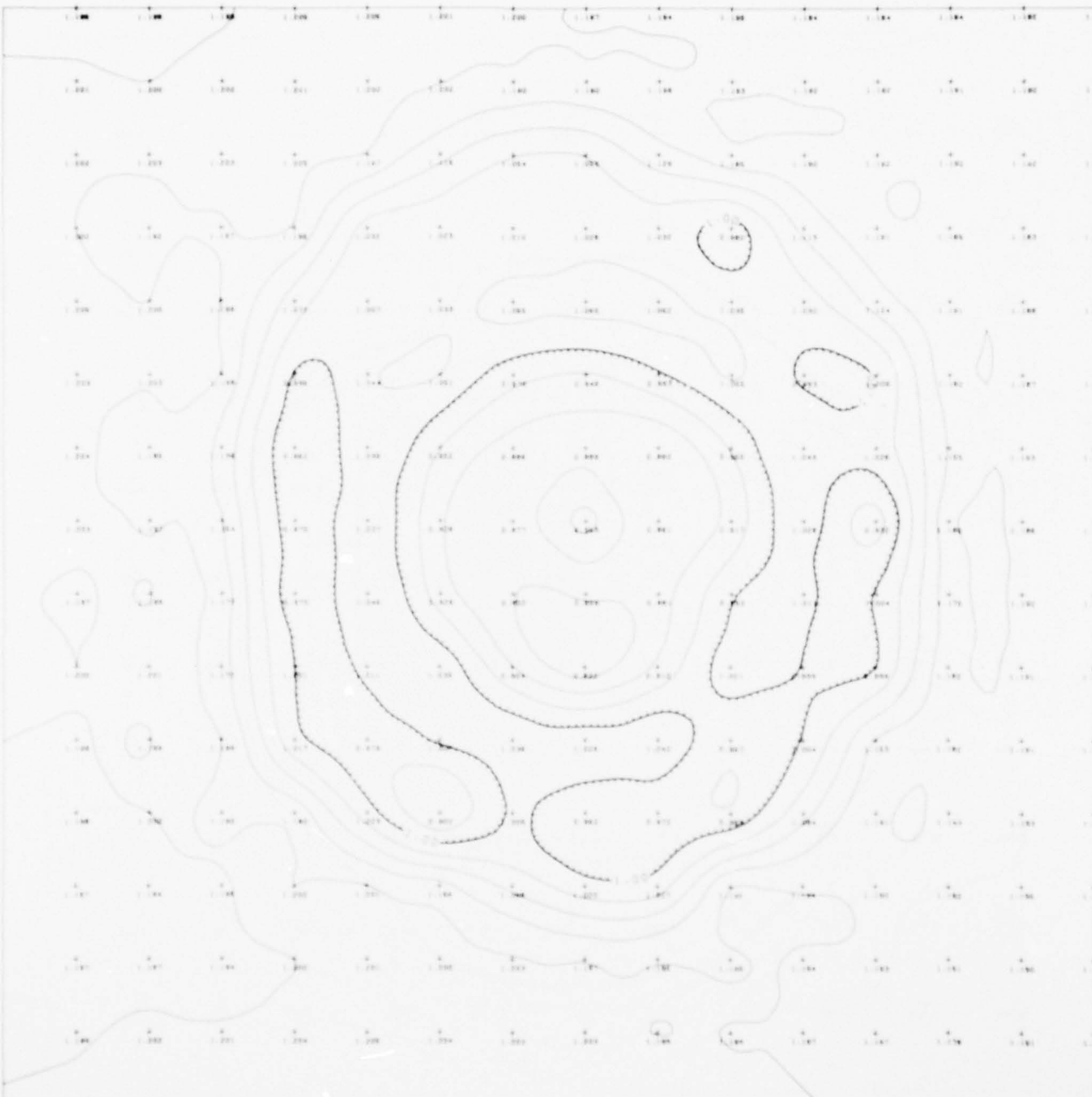
FR-1; 90° 0.5 Ft, Rocket Motor Mk 36



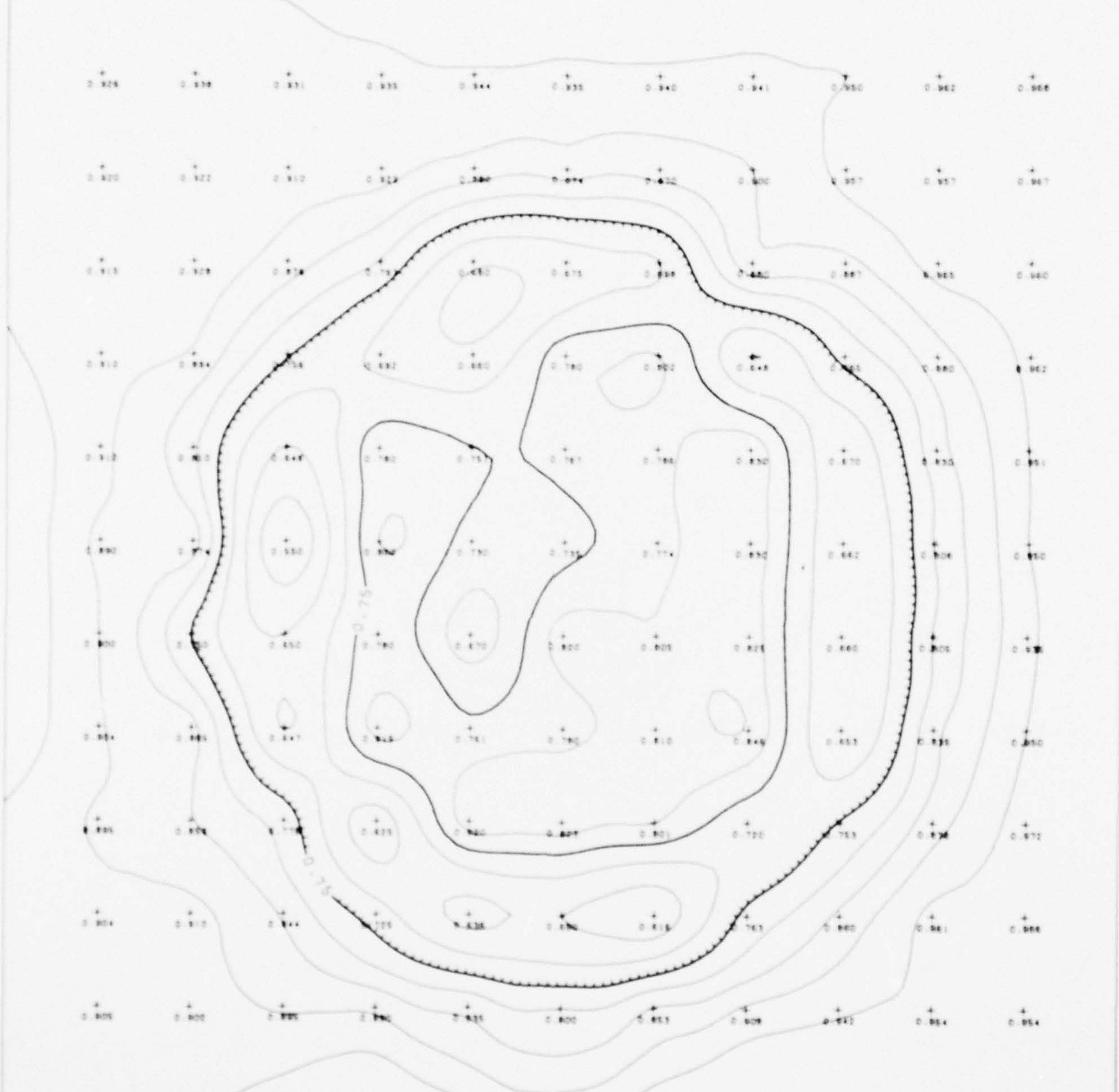
MXBE-350; 90° 0.5 Ft, Rocket Motor Mk 36



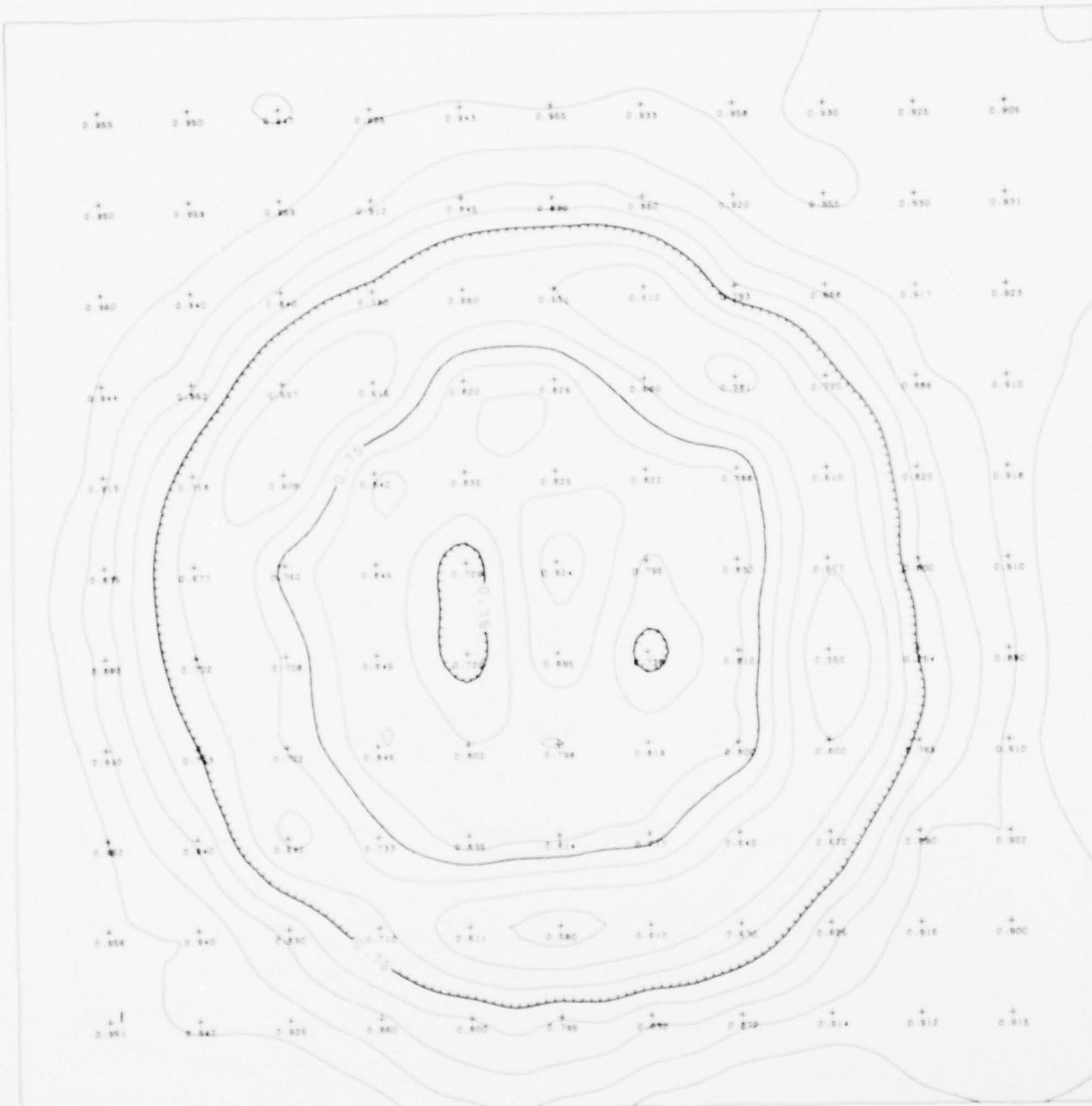
MXB-360; 90° 0.5 Ft, Rocket Motor Mk 36



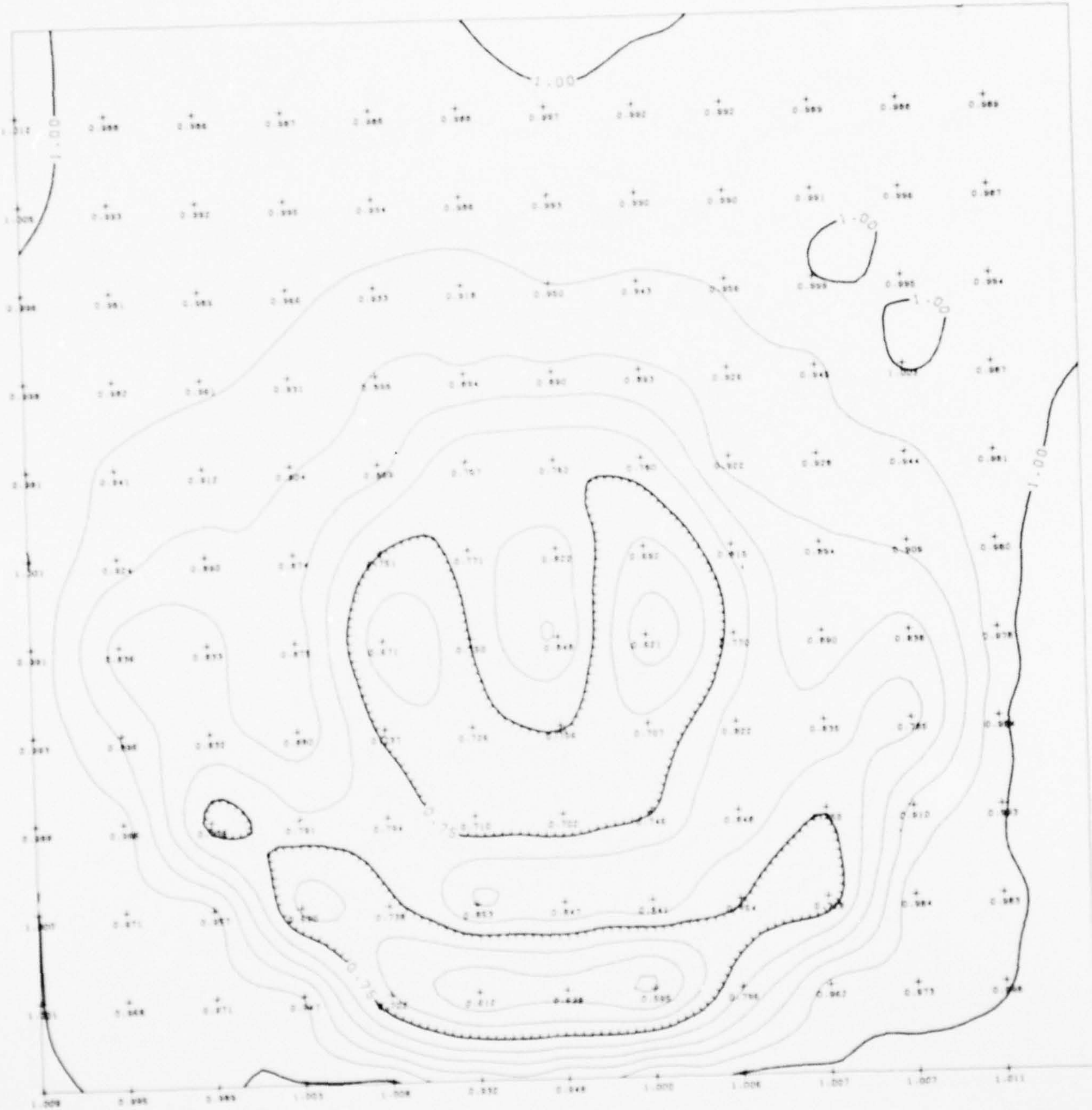
GER 1-A; 90° 0.5 Ft, Rocket Motor Mk 36



FR-1; 90° 0.5 Ft, Rocket Motor Mk 36



FR-1; 90° 0.5 Ft, Rocket Motor Mk 36



FR-1; 15° 0.5 Ft, Rocket Motor Mk 36

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